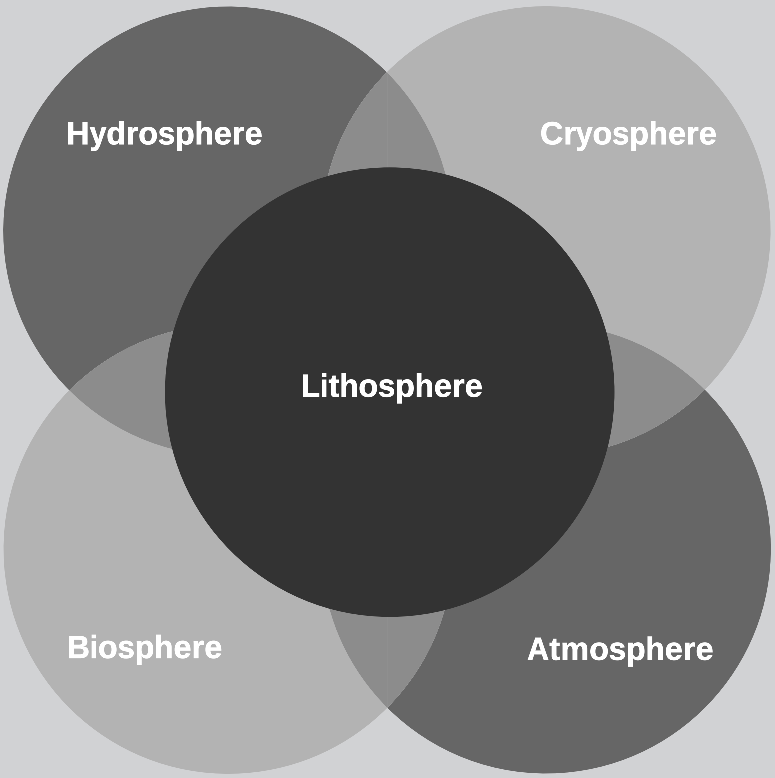
U.S. Department of the Interior
U.S. Geological Survey

TEACHING GUIDE

VOLCANOES!

fig. 1

The Earth's Systems



The Earth is a system comprising interactive components.

Volcanoes is an interdisciplinary set of materials for grades 4-8. Through the story of the 1980 eruption of Mount St. Helens, students will answer fundamental questions about ***volcanoes***: "What is a volcano?" "Where do volcanoes occur and why?" "What are the effects of volcanoes on the Earth system?" "What are the risks and the benefits of living near volcanoes?" "Can scientists forecast volcanic eruptions?"

This teaching packet reflects the goals of the National Science Education Standards developed by the National Research Council. These standards recommend that middle school students be able to understand the Earth as a system. By learning about volcanoes, students will understand that the Earth comprises interacting components, or subsystems: the ***geosphere*** and the ***biosphere***. In turn the geosphere comprises the lithosphere, the atmosphere, the hydrosphere, and the cryosphere. *(fig. 1)* These lessons show how the eruption of Mount St. Helens affected all of the Earth's subsystems.

Although volcanoes is an earth science subject, the activities in this packet incorporate a number of related subjects, including other sciences, social studies, language arts, and mathematics.

Contents of this packet

- Two-sided color poster
- Teaching guide (with glossary and bibliography)
- Six lesson plans with timed activities
- Evaluation sheet

About the poster

The poster is a key visual aid for many of the activities. Side 1 is a dramatic photograph of Mount St. Helens erupting on May 18, 1980. Side 2 is a series of photographs and illustrations annotated with text written for student readers. The section titled "Volcanoes" is a basic introduction to volcanoes and volcanic eruptions. The section titled "Mount St. Helens" tells the story of the May 18, 1980, eruption of Mount St. Helens and the effect the eruption had on each of the components of the Earth system.

Each photograph and diagram has a number. When lessons refer to specific photographs and illustrations, they are referenced as "*poster fig.*" followed by the number of the photograph or diagram.

About the lessons

Each lesson includes:

- Illustrated background information
- Two step-by-step, timed activities
- Reproducible Master Sheets for making overhead transparencies or photocopies
- Reproducible Activity Sheets for your students

There are six lessons. Lesson 1 and Lesson 2 should be taught in sequence. Lesson 6 is probably best suited as a wrap-up. Many of the activities are demonstrations that will help students, particularly elementary-level students, visualize the physical, chemical, geologic, and biologic processes being presented.

Lesson 1: Windows into the Earth

*The **lithosphere** is the Earth's hard, outermost shell that is divided into a mosaic of 16 major slabs, or plates.*

The first lesson introduces the nature of volcanoes and volcanic eruptions. In addressing how and where volcanoes occur, students learn that volcanic eruptions are geologic events that take place within the upper part and on the surface of the Earth's lithosphere.

Volcanic eruptions, however, can impact all of the Earth's systems, including the lithosphere itself: Volcanic eruptions create volcanic mountains. A key point is that understanding how and where volcanoes occur helps students understand the dynamic nature of the Earth's geologic processes.

Lesson 2: Creators and Destroyers

This lesson continues to explain how volcanoes are related to the Earth's ***lithosphere***. With a basic understanding of how volcanoes erupt, students focus on the May 18, 1980, eruption of Mount St. Helens. They see how changes to the volcano's shape in the month prior to the eruption reflected changes that were taking place inside of the volcano. They also learn that volcanic eruptions can destroy the landforms they help create. The May 18, 1980, eruption of Mount St. Helens is a dramatic example of both creation and destruction.

Lesson 3: Up in the Air

*The **atmosphere** is the mixture of gases that envelops the Earth.*

This lesson explains how volcanoes can affect the atmosphere. Students learn that volcanic eruptions affect places ten to thousands of miles from an eruption site because of the ejection of volcanic rock fragments, gases, and ***aerosols*** into the atmosphere. They also discover that volcanoes do not have to erupt to have an effect on the atmosphere. The presence of volcanic mountains, such as the Cascade Range in the Pacific Northwest, continually affect atmospheric conditions, and hence the climate, of the region.

Lesson 4: Fire, Water, and Ice

*The **hydrosphere** and **cryosphere** are the subsystems that contain the Earth's water. The hydrosphere is the water on the Earth's surface contained in oceans, lakes, rivers, and streams, as well as ground water that circulates within the upper part of the lithosphere. The cryosphere is water on the Earth's surface in its frozen state, such as **glaciers**; snow; sea, lake, and river ice; and **permafrost** (permanently frozen ground).*

This lesson explains how water from the hydrosphere and cryosphere can combine with volcanic materials from the lithosphere to produce catastrophic ***mudflows*** and floods. Students see the relationship between where mudflows and floods are likely to occur and a volcano's topography. They also discover why snow and ice cap many volcanic mountains and that the potential melting of ice and snow adds to the volcanic hazards on these mountains.

Lesson 5: Death and Recovery

*The **biosphere** is the realm of all living things, including humans.*

This lesson addresses the effect volcanic eruptions can have on the biosphere—the realm of all living things. Students learn that while the eruption of Mount St. Helens claimed about 60 human lives, the toll on wildlife and plants was incalculable. By interpreting a set of ***tree rings***, students discover that a volcanic eruption can have positive as well as negative effects on plant growth. Finally, students examine the role that eyewitness accounts played in helping scientists reconstruct the events of the May 18, 1980, eruption of Mount St. Helens, reinforcing the importance of first-hand observation as a scientific tool of investigation.

Lesson 6: Living with Volcanoes

The final lesson addresses the fact that volcanic eruptions can occur in populated areas. Students discover that people who have lived with volcanoes have attempted to understand the volcano's presence and behavior—using legends and folklore for most of human history. Students see how, today, scientists reconstruct the history of a volcano's eruptions to understand the potential hazards of future eruptions. Students conclude the lesson by creating materials that they could use to explain volcanoes and their hazards to a community living near an active volcano.

A word about map skills

Many of the activities included in these lessons require basic map skills. Students should know how to read simple maps, such as road maps. They also need to understand the following concepts:

- Basic compass directions (north, south, east, and west)
- Using a map scale to determine distance between two points
- Using a map legend, or key, to interpret basic map symbols
- Locating places on the basis of longitude and latitude

The U.S. Geological Survey's teaching packet *What Do Maps Show?* is an excellent introduction to map reading for upper elementary and junior high school students. You may want to review it before teaching the topographic map skills used in Lessons 2, 4, and 6.

To obtain copies of this packet and other USGS educational materials and publications:

Call 1-800-USA-MAPS, or write or visit a USGS Earth Science Information Center.

Glossary

Active volcano: A volcano that is currently erupting, or has erupted during recorded history.

Aerosol: Fine liquid or solid particles suspended in the atmosphere. Aerosols resulting from volcanic eruptions are tiny droplets of sulfuric acid—sulfur dioxide that has picked up oxygen and water.

Ash: Fragments less than 2 millimeters (about ⅛ inch) in diameter of lava or rock blasted into the air by volcanic explosions.

Atmosphere: The mixture of gases, aerosols, solid particles, and water vapor that envelops the Earth.

Biosphere: The realm of all living things.

Crater: The circular depression containing a volcanic vent.

Cinder cone: A steep-sided volcano formed by the explosive eruption of cinders that form around a vent. Cinders are lava fragments about 1 centimeter (about ½ inch) in diameter.

Crust: The Earth's outermost layer.

Contour lines: Parallel lines used on topographic maps to show the shape and elevation of the land. They connect points of equal elevation.

Cryosphere: The ice and snow on the Earth's surface, such as glaciers; sea, lake, and river ice; snow; and permafrost.

Dome: A steep-sided mound that forms when very viscous lava is extruded from a volcanic vent.

Dormant volcano: An active volcano that is in repose (quiescence) but is expected to erupt in the future.

Extinct volcano: A volcano that is not expected to erupt again.

Geosphere: The nonliving parts of the Earth: the lithosphere, the atmosphere, the cryosphere, and the hydrosphere.

Glacier: A thick mass of ice resulting from compacted snow that forms when more snow accumulates than melts annually.

Harmonic tremor: Continuous rhythmic earthquakes in the Earth's upper lithosphere that can be detected by seismographs. Harmonic tremors often precede or accompany volcanic eruptions.

Hot spot: An area in the middle of a lithospheric plate where magma rises from the mantle and erupts at the Earth's surface. Volcanoes sometimes occur above a hot spot.

Hydrosphere: The water that covers 71 percent of the Earth's surface as oceans, lakes, rivers, and streams. The hydrosphere also includes ground water, water that circulates below the Earth's surface in the upper part of the lithosphere.

Lateral blast: A sideways-directed explosion from the side or summit of a volcano.

Lava: The term used for magma once it has erupted onto the Earth's surface.

Leeward: The side of a land mass sheltered from the wind—the opposite of windward.

Lithosphere: The Earth's hard, outermost shell. It comprises the crust and the upper part of the mantle and is divided into a mosaic of 16 major slabs, or plates.

Lithospheric plates: A series of rigid slabs (16 major ones at present) that make up the Earth's outer shell. These plates float on top of a softer, more plastic layer in the Earth's mantle. (Also called tectonic plates.)

Magma: Molten rock containing liquids, crystals, and dissolved gases that forms within the upper part of the Earth's mantle and crust. When erupted onto the Earth's surface, it is called lava.

Mantle: A zone in the Earth's interior between the crust and the core that is 2,900 kilometers (1,740 miles) thick. (The lithosphere is composed of the topmost 65-70 kilometers (39-42 miles) of the mantle and the crust.)

Mudflow: A flowing mixture of water and debris (intermediate between a volcanic avalanche and a water flood) that forms on the slopes of a volcano. Sometimes called a debris flow or lahar, a term from Indonesia where volcanic mudflows are a major hazard.

Permafrost: Permanently frozen ground at high latitude and high elevation.

Prevailing winds: The direction from which winds most frequently blow at a specific geographic location.

Seismograph: A scientific instrument that detects and records vibrations (seismic waves) produced by earthquakes.

Shield volcano: A volcano that resembles an inverted warrior's shield. It has long gentle slopes produced by multiple eruptions of fluid lava flows.

Snowline: The lowest elevation at which snow remains from year to year and does not melt during the summer.

Spreading ridges: Places on the ocean floor where lithospheric plates separate and magma erupts. About 80 percent of the Earth's volcanic activity occurs on the ocean floor.

Stratovolcano: A steep-sided volcano built by lava flows and tephra deposits. (Also called composite volcano.)

Subduction zone: The place where two lithospheric plates come together, one riding over the other. Most volcanoes on land occur parallel to and inland from the boundary between the two plates.

Tephra: Solid material of all sizes explosively ejected from a volcano into the atmosphere.

Topographic map: A map that uses contour lines to represent the three-dimensional features of a landscape on a two-dimensional surface.

Tree rings: Concentric rings formed annually as a tree grows.

Vent: The opening at the Earth's surface through which volcanic materials (lava, tephra, and gases) erupt. Vents can be at a volcano's summit or on its slopes; they can be circular (craters) or linear (fissures).

Viscosity: Measure of the fluidity of a substance. Taffy and molasses are very viscous; water has low viscosity.

Volcano: A vent (opening) in the Earth's surface through which magma erupts; it is also the landform that is constructed by the eruptive material.

Volcanic avalanche: A large, chaotic mass of soil, rock, and volcanic debris moving swiftly down the slopes of a volcano. Volcanic avalanches can also occur without an eruption as a result of an earthquake; heavy rainfall; or unstable soil, rock, and volcanic debris. (Also called debris avalanche.)

Windward: The side of a land mass facing the direction from which the wind is blowing—the opposite of leeward.

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The U.S. Geological Survey

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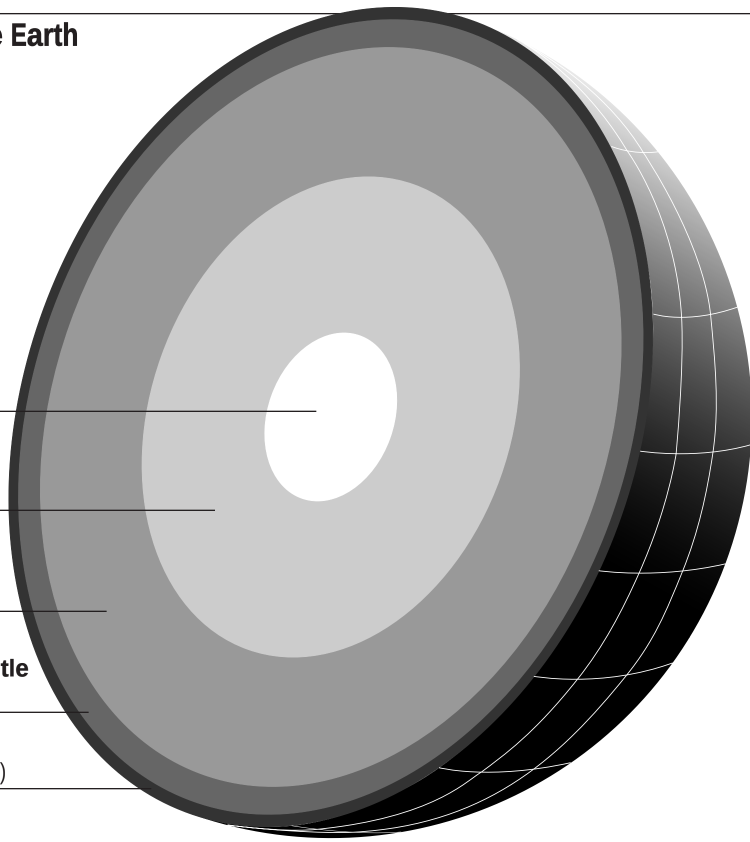
WINDOWS INTO THE EARTH

VOLCANOES!

LESSON 1

fig. 1

Inside the Earth



Magma is generated in the Earth's lithosphere, which is made up of the crust and upper mantle.

Until the spring of 1980, most people thought of Mount St. Helens as a serene, snow-capped mountain and not as a lethal ***volcano***. The mountain had given little evidence that it posed a hazard for more than a century—a long time in human terms but a blink of an eye in terms of the mountain's 50,000-year geologic history. A series of earthquakes that began in mid-March of 1980 sounded the alarm that Mount St. Helens was awakening from its sleep. In other words, Mount St. Helens, which had been ***dormant***, became ***active*** and likely to erupt. Its catastrophic eruption 2 months later was a reminder that a fiery world lies beneath the Earth's surface.

Why Volcanoes Occur

The roots of Mount St. Helen's are 110 to 330 kilometers (70 to 200 miles) below the Earth's surface. Here in the Earth's ***mantle*** (*fig. 1*) temperatures are hot enough to melt rock and form a thick, flowing substance called ***magma***. Lighter than the solid rock that surrounds it, magma is buoyant much like a cork in water; being buoyant, it rises.

As the magma rises, some of it collects in large reservoirs, or magma chambers (*poster fig. 1*) that fuel volcanoes. As the rising magma nears the Earth's surface, pressure decreases, which causes the gases in the magma to expand. This expansion propels the magma through openings in the Earth's surface: a volcanic eruption occurs. Once magma is erupted, it is called ***lava***.

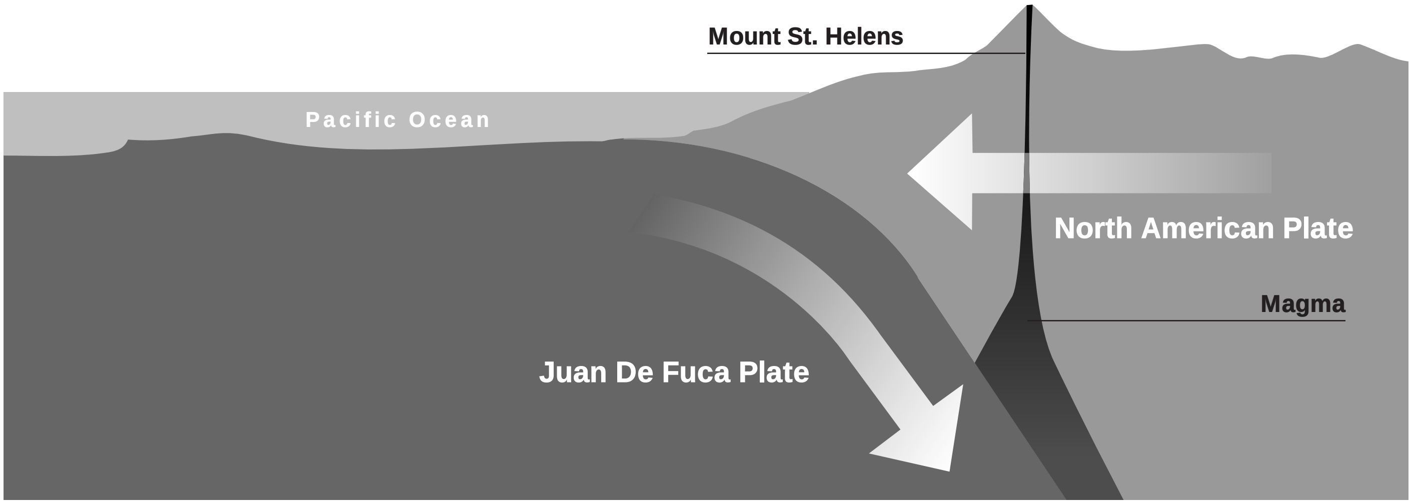
Where Volcanoes Occur

Volcanic eruptions occur only in certain places and do not occur randomly. That's because the Earth's outermost shell—the ***lithosphere***—is broken into a series of slabs known as ***lithospheric*** or ***tectonic plates***. These plates are rigid, but they float on the hotter, softer layer in the Earth's mantle. (*poster fig. 2)* As the plates move about, they spread apart, collide, or slide past each other. Volcanoes occur most frequently at plate boundaries.

Some volcanoes, like those that form the Hawaiian Islands, occur in the interior of plates at areas called ***hot spots***. (*poster fig. 2*) Although most of the active volcanoes we see on land occur where plates collide, the greatest number of the Earth's volcanoes are hidden from view, occurring on the ocean floor along ***spreading ridges***.

Mount St. Helens is typical of more than 80 percent of the volcanoes that have formed on land. Known as ***subduction zone*** volcanoes, they occur along the edges of continents where one plate *fig. 2*

Inside the Earth



About 240 kilometers (150 miles) west of the northwest coast of the United States, the Juan de Fuca Plate plunges beneath the North American Plate. Mount St. Helens is among the volcanoes that have formed as a result.

dives, or subducts, beneath a second plate. (*fig. 2*). When the subducting plate reaches about 100 kilometers (60 miles) into the Earth's hot mantle, it triggers partial melting of the overlying plate and forms new magma. Some of the magma rises and erupts as volcanoes.

Why Some Volcanoes Erupt

Some volcanoes, like Mount St. Helens, tend to be explosive when they erupt, whereas others, like Hawaii's Kilauea, tend to be effusive (loosely flowing) and nonexplosive. How explosive an eruption is depends on the magma's chemical composition and gas content, which in turn affect the magma's stickiness, or ***viscosity***.

All magma contains gases that escape as the magma travels to the Earth's surface. If magma is fluid (as is Kilauea's), gases can escape relatively rapidly. As a result, lava flows instead of exploding during an eruption. If magma is viscous (as is Mount St. Helens), the gases cannot escape easily; pressure builds inside the magma until the gases sometimes escape violently.

In an explosive eruption, the sudden expansion of gases blasts magma into airborne fragments called ***tephra***, which can range in size from fine particles of ash to giant boulders. After the initial explosive phase of the eruption, however, quieter lava flows can follow. In both explosive and nonexplosive (effusive) eruptions, volcanic gases, including water vapor, are released into the atmosphere.

Three Types of Volcanoes

Repeated volcanic eruptions build volcanic mountains of three basic types, or shapes, depending on the nature of the materials deposited by the eruption.

Shield volcanoes (*poster fig. 5*)**,** such as Kilauea, form by effusive eruptions of **fluid lava**. Lava flow upon lava flow slowly builds a broad, gently sloping volcanic shape that resembles a warrior's shield.

Stratovolcanoes (*poster fig.4*)**,** such as Mount St. Helens, build from both explosive and effusive eruptions. **Layers of tephra** alternating with **layers of viscous lava** flows create steep-sided, often symmetrical cones that we think of as the classic volcano shape. In his log of the Lewis and Clark Expedition, William Clark wrote: "Mount St. Helens is perhaps the greatest pinnacle in America."

The smallest volcanoes, ***cinder cones*** (*poster fig. 3*), such as Sunset Crater in Arizona, form primarily from explosive eruptions of lava. Blown violently into the air, the erupting **lava breaks apart into fragments called cinders**. The fallen cinders accumulate into a cone around the volcano's central vent. Cinder cones can form on the flanks of shield and stratovolcanoes.

Activity 1 How Volcanoes Grow

45-minute work session
45-minute demonstration
and discussion
In small groups, students **build models** of the three major types of volcanoes and see how a volcano's shape is related to the type of material it erupts. As a class, they **observe a demonstration** that simulates the nature of two volcanic materials: lava and tephra. The lesson concludes with a **discussion** of how a volcano's shape is related to the nature of the material it erupts.

Key teaching points

1. A volcano is a circular or linear opening in the Earth's surface through which lava, rock fragments, ***ash***, ***aerosols***, and gases erupt.

2. A volcano is also the landform, often a mountain, built from repeated eruptions.

3. Some eruptions are explosive, some are effusive (loosely flowing) and nonexplosive, and some are both explosive and effusive.

4. There are three major types, or shapes, of volcanoes: (a) stratovolcano, (b) shield volcano; and (b) cinder cone.

Materials

Work Session

1. Master Sheets 1.1, 1.2, and 1.3
2. Colored marking pens (optional)
3. Three 8 ½" x 11" transparencies for overhead projection
4. Playdo® in several colors
5. Construction paper or cardboard, one piece for each group of four students
6. Pencils

Demonstration

1. Three pie plates
2. Three 1-cup measuring cups
3. Cat litter
4. Chilled molasses

Procedures

1. Explain that the photograph on *side 1 of the poster* was taken during the 1980 eruption of Mount St. Helens, a volcano located in the western United States.

2. Introduce the concept that a volcano is both an opening in the Earth's surface through which magma erupts and a landform.

3. Discuss the types of materials that can be erupted: lava, tephra, cinders.

4. Discuss the different styles of eruption: explosive and nonexplosive.

5. At this point, **do not** name the three major volcanic shapes.

6. Divide the class into groups of four students each. Distribute to each group:
- Master Sheets 1.1, 1.2, and 1.3
- Three pieces of cardboard or construction paper
- Play-doh®

7. Using the Master Sheets as guides, each group of students creates a two-dimensional relief model for each of the three types of volcanoes. Master Sheet 1.1 is a **stratovolcano**, Master Sheet 1.2 is a **cinder cone**, and Master Sheet 1.3 is a **shield volcano**.

8. Ask each group of students to list the similarities and differences among the shapes and composition of the three types. (The shield is broad; the stratovolcano has steep sides; the cinder cone is the smallest; and the shield has only layers of lava.)

Discussion

1. On a chalkboard, compile a class list of similarities and differences for each of the three types.

2. Brainstorm why the volcanoes are different. For example, lava is runny like molasses so it spreads out.

Demonstration

1. Do the following demonstration to simulate the nature of lava and the nature of tephra. In one pie plate, slowly pour 1 cup of cat litter (tephra). In a second pie plate, slowly pour 1 cup of chilled molasses (lava).
2. Discuss how the nature of the material influenced the shape of the material built. Discuss what shape you would expect to get if you alternated a layer of cat litter with a layer of molasses. In the third pie plate, layer molasses and cat litter.

3. Compare the results of your demonstration with the shapes of the three types of volcanoes (*poster fig. 3–5*). Ask student to "type" each of their models.

4. Show students *side 1 of the poster*. What type of volcano is Mount St. Helens? (stratovolcano) What type of eruptions does it have? (explosive) What type of material is in the cloud rising above it ? (tephra)

Activity 2 Ring of Fire

30 minutes
Students locate some of the 1,500 active volcanoes on a world map. Then by comparing their maps with a map of the world's tectonic plates, they discover that volcanoes occur because of the dynamic nature of the Earth's lithosphere—the crust and upper mantle.

Key teaching points

1. Volcanoes are windows into how the Earth works. They occur because the Earth's rigid outer shell, the crust and upper mantle, is broken into a mosaic of plates that are in constant motion.

2. Most volcanoes occur along the boundaries of the Earth's tectonic plates.

3. More than half of the volcanoes that are exposed on land form a chain along the converging plates that encircle the Pacific Ocean. This chain is called the "Ring of Fire."

4. Mount St. Helens is located in the "Ring of Fire."

Materials

1. A photocopy of Activity Sheets 1.2 and 1.2b for each student
2. Master Sheets 1.4 and 1.5
3. Two 8 ½" x 11" transparencies for overhead projection
4. Colored pencils

Procedures

Preparation

1. Make transparencies of Master Sheets 1.4–1.5.
2. Distribute Activity Sheets 1.2a–1.2b and ask each student to read the Activity Sheets.

Discussion

1. After the students have completed their maps, lead a discussion. Are there volcanoes on every continent? (yes) How many of the volcanoes on their map are located within the shaded area, "The Ring of Fire?" (14)

2. Show the class the transparency of Master Sheet 1.5, the "Plate Tectonics Map." With a colored marker, trace the plate outlines. Tell students that the outer layer of the Earth is broken into a series of 16 major plates and that the colored lines indicate the boundaries between these plates.

3. Next, superimpose the transparency of Master Sheet 1.4, "Volcanoes Map," on Master Sheet 1.5, the "Plate Tectonics Map."

4. Ask students to observe the location of the volcanoes in relationship to the plates. Where do most of the volcanoes occur? They should observe that most occur near plate boundaries. Is the "Ring of Fire" located near plate boundaries?

5. Use (*poster fig. 2)* to explain that rigid plates float on top of a softer layer of rock. As the plates move, they push together, pull apart, or slide past each other. Along two plate boundaries, magma comes to the surface and volcanoes can occur.

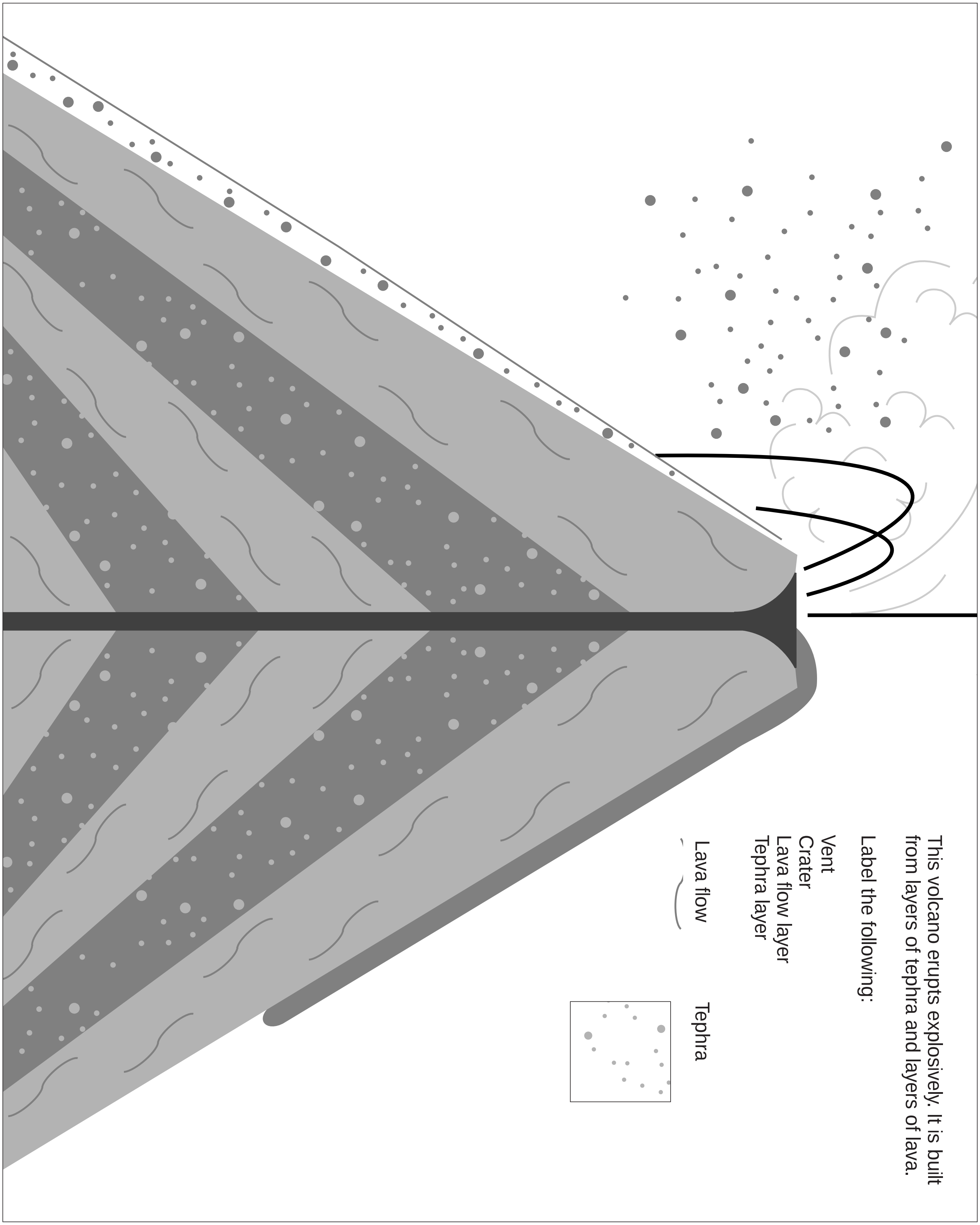
6. Explain that there are some volcanoes that occur in the interior of plates and not at plate boundaries. They occur over "hot spots" in the plates. Scientists do not know exactly why hot spots develop, but hot spots are places in the Earth's interior from which magma rises and erupts through the plate as it moves over the hot spot. Ask students which U.S. State is composed primarily of shield volcanoes? (Hawaii)

7. Is Mount St. Helens located in the "Ring of Fire"? (Yes)

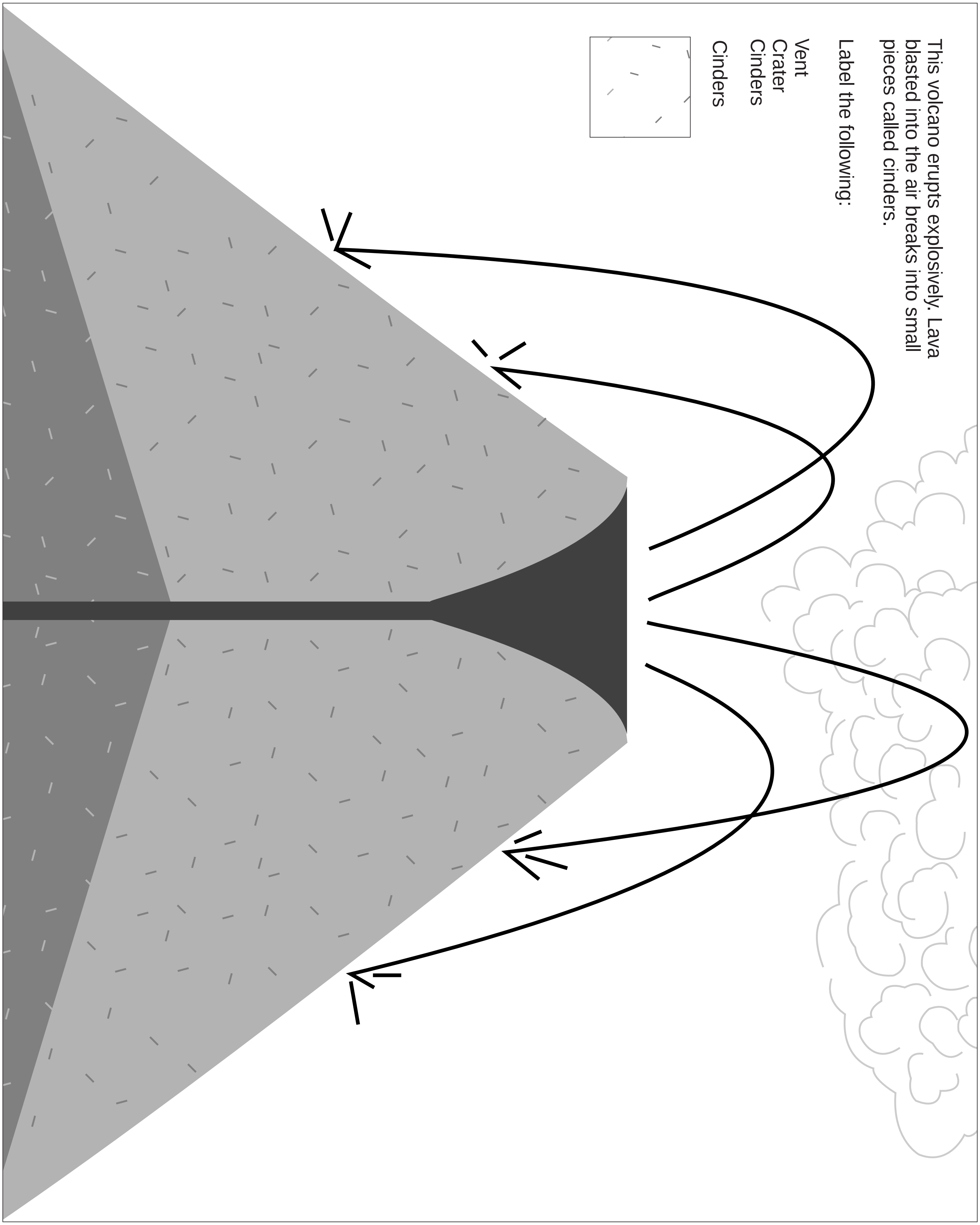
Activity Sheet 2 Answers

1. Yes
2. 66.6%
3. 33.3%
4. 14 stratovolcanoes; 1 shield; 8 cindercone
5. Stratovolcano
6. Answers will vary

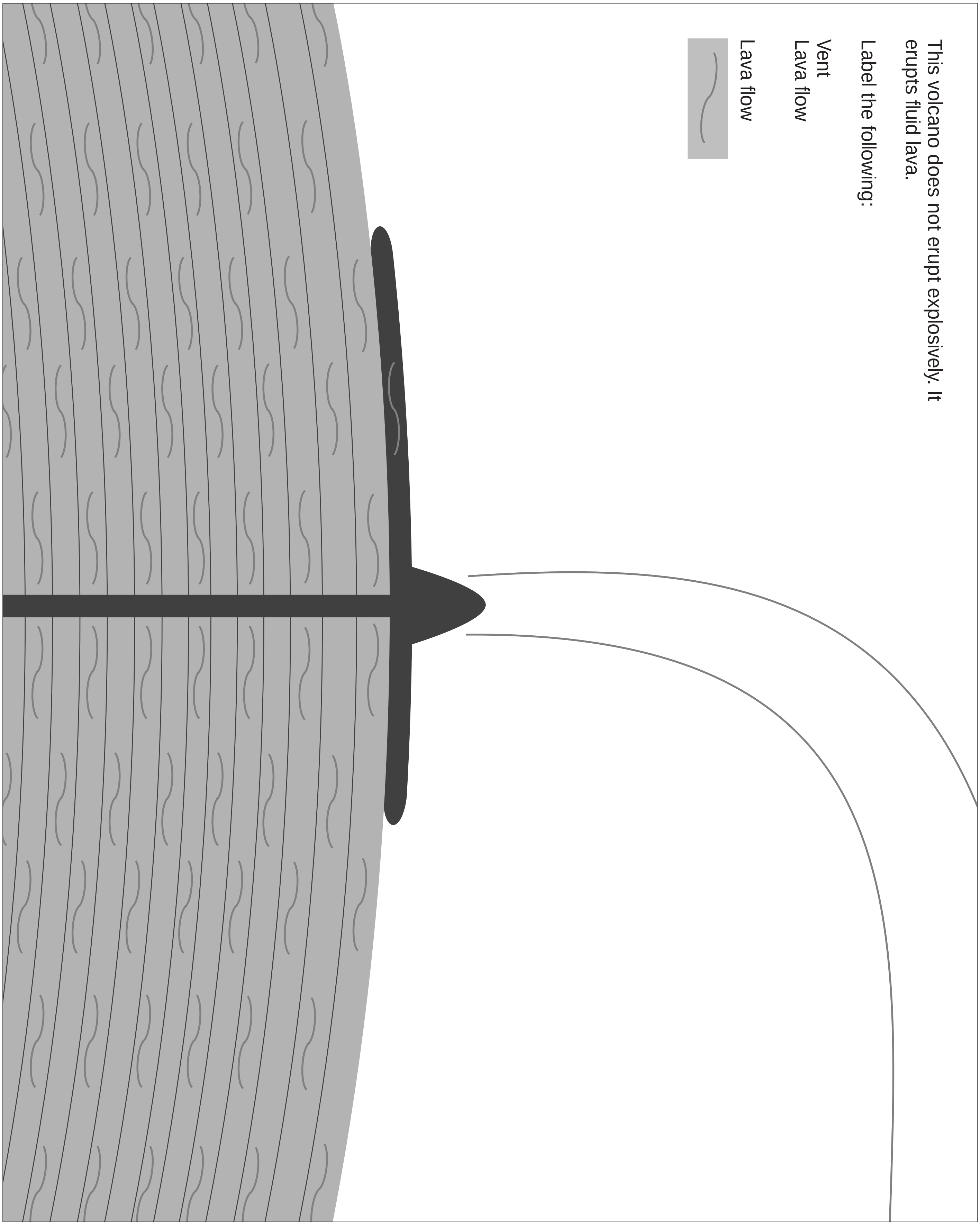
Master Sheet 1.1



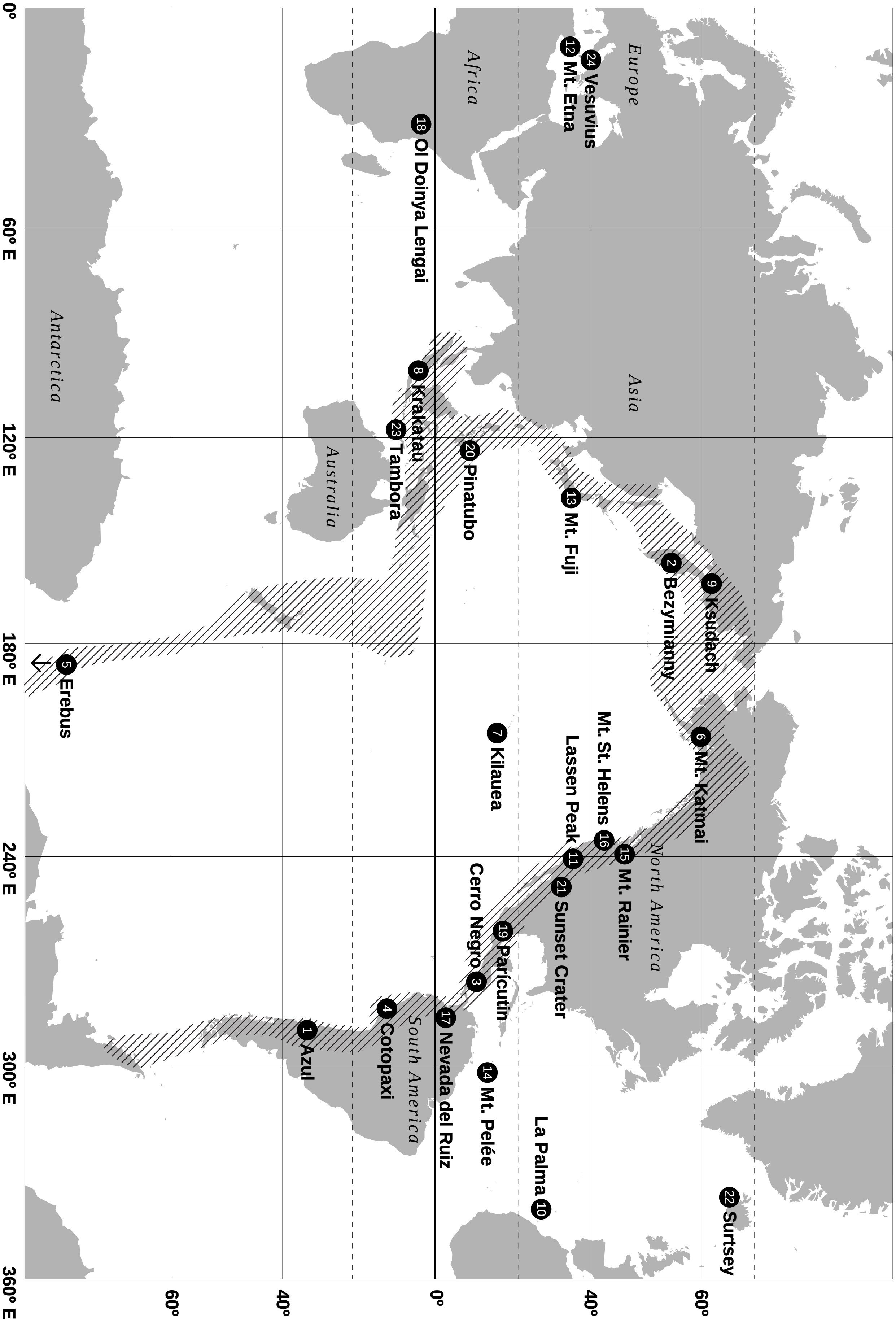
Master Sheet 1.2



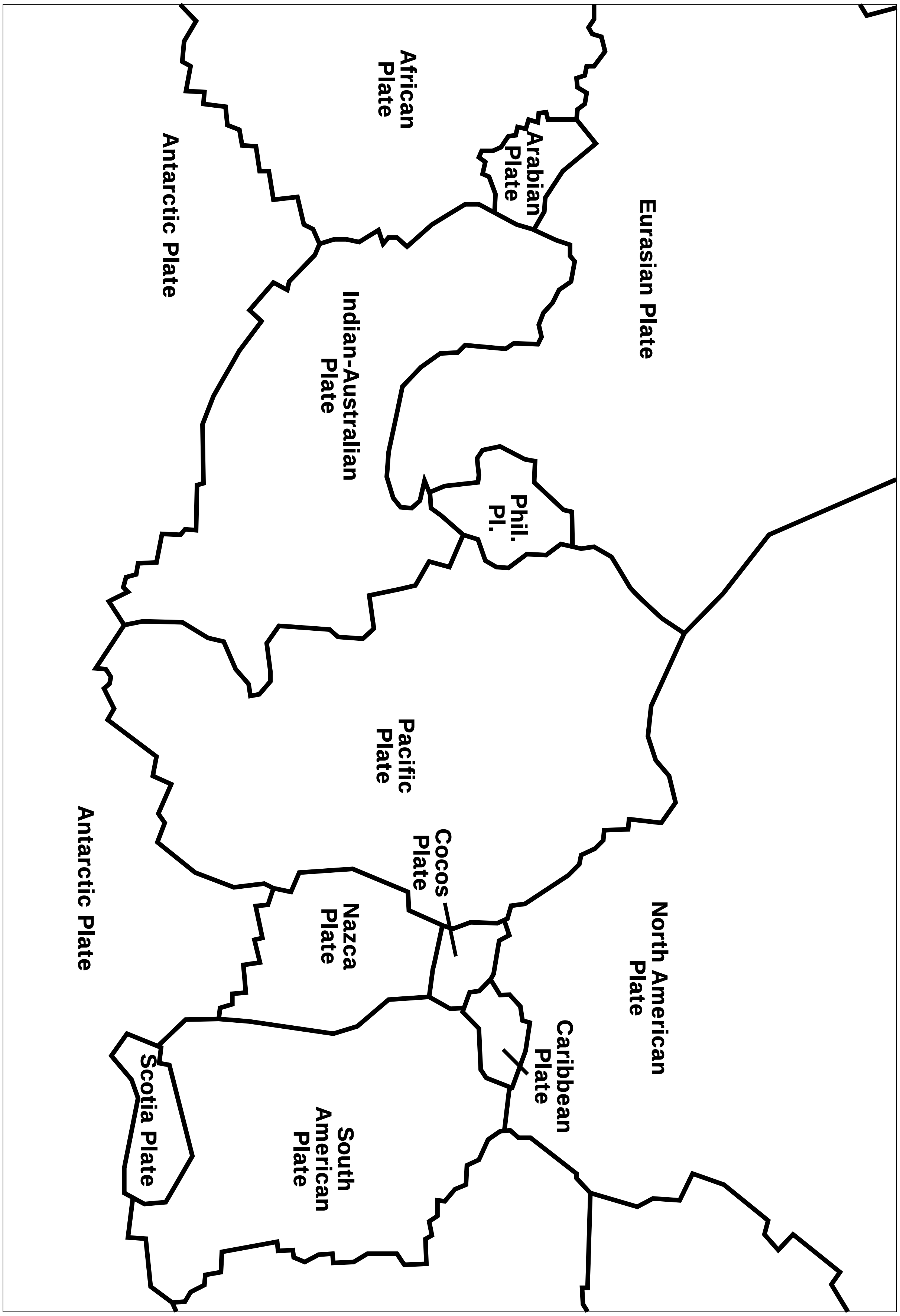
Master Sheet 1.3



Master Sheet 1.4



Master Sheet 1.5



VOLCANOES!

Activity Sheet 1.2a
The "Ring of Fire"

There are more than 1,500 ***active volcanoes*** *in the world. An active volcano is one that has erupted at least once in the past 10,000 years and is likely to erupt again. Because most of the Earth's volcanoes are hidden under the oceans, people have not been able to witness their eruptions. Every year, about 50-60 volcanoes erupt on land where people might be able to see them. Scientists estimate that there are about 200 volcanic eruptions under the oceans.*
The shaded area on your map is called the "Ring of Fire." Do the exercise below and you will discover why.

What to do

Locate and label each of the volcanoes listed on the blank map. Use a different colored marker for ***stratovolcano, shield,*** and ***cinder cone*** volcanoes.

1. Are most of the volcanoes located in the Ring of Fire?

____

2. What percentage of the volcanoes are located in the Ring of Fire? To find out use the following formula:

$$\frac{\text{\# in shaded area}}{\text{total \#}} \times 100 = \_\_\_\_\_$$ % of volcanoes in the Ring of Fire

3.What percentage of the volcanoes are located outside of the Ring of Fire? To find out use the following formula:

$$\frac{\text{\# not in shaded area}}{\text{total \#}} \times 100 = \_\_\_\_\_$$ % outside of volcanoes in the Ring of Fire

4.Types of volcanoes in the Ring of Fire

# of stratovolcanoes ____

# of shield volcanoes ____

# of cinder cones ____

5. What type of volcano is most common in the Ring of Fire?

____

6. How many of the volcanoes listed have erupted since you were born?

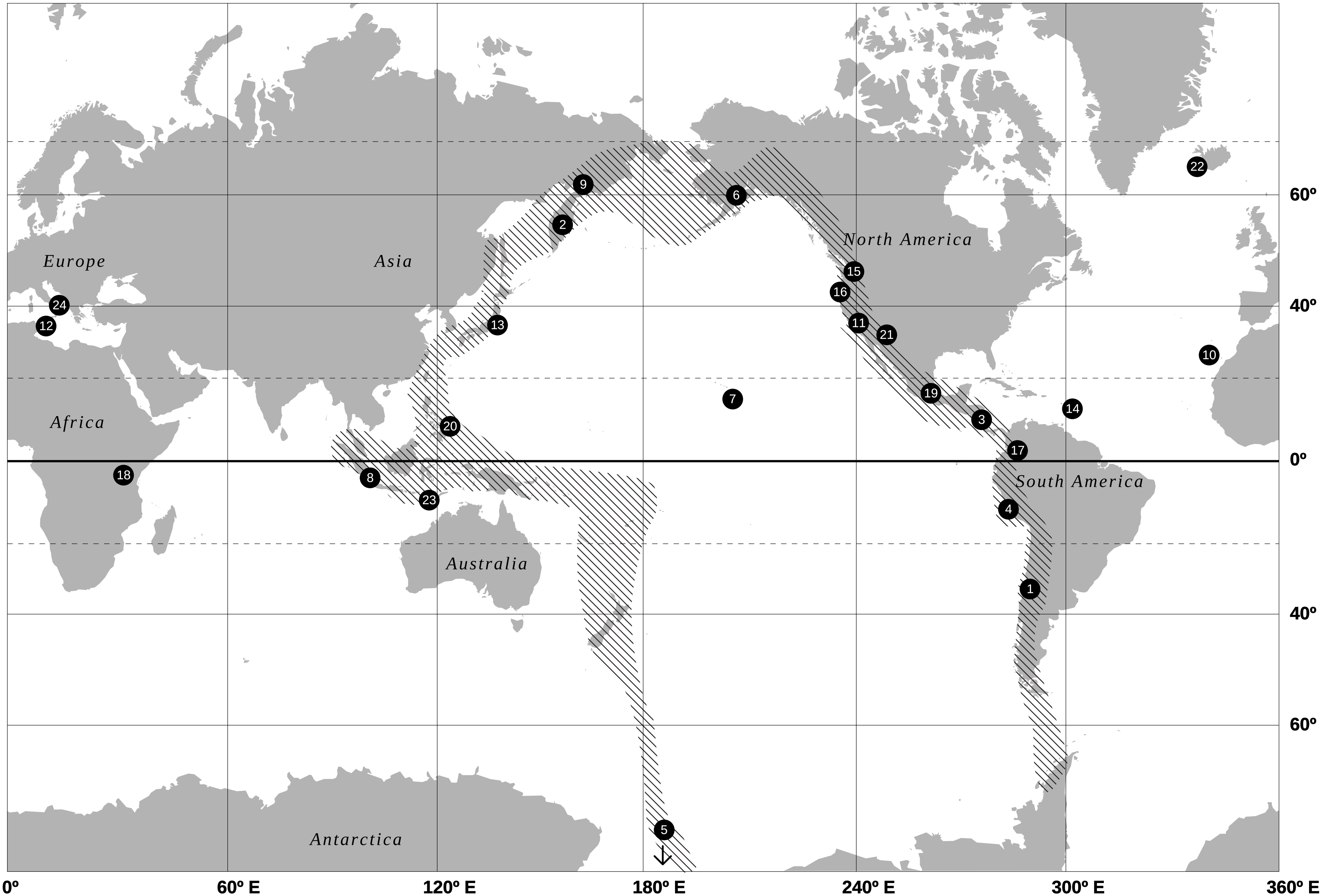
____

This is a list of some active, or recently active, volcanoes.

	Name	*Type*	*Last Erupted*
1	Azul	Stratovolcano	1967
2	Bezymianmy	Stratovolcano	1993
3	Cerro Negro	Cinder cone	1971
4	Cotopaxi	Stratovolcano	1942
5	Erebus	Stratovolcano	1980
6	Katmai	Stratovolcano	1912
7	Kilauea	Shield	1995
8	Krakatau	Stratovolcano	1894
9	Ksudach	Shield	1907
10	La Palma	Stratovolcano	1954
11	Lassen Peak	Stratovolcano	1914
12	Mt. Etna	Shield	1993
13	Mt. Fuji	Stratovolcano	1709
14	Mt. Pelée	Stratovolcano	1932
15	Mt. Rainier	Stratovolcano	1894
16	Mount St. Helens	Stratovolcano	1986
17	Nevada del Ruiz	Stratovolcano	1991
18	Ol Doinyo Lengai	Stratovolcano	1993
19	Parícutin	Cinder cone	1952
20	Pinatubo	Stratovolcano	1992
21	Sunset Crater	Cinder cone	1065
22	Surtsey	Shield	1967
23	Tambora	Stratovolcano	1967
24	Vesuvius	Stratovolcano	1944

VOLCANOES!

Activity Sheet 1.2b
The "Ring of Fire"



U.S. Department of the Interior
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VOLCANOES! CREATORS AND DESTROYERS

LESSON 2

On May 18, 1980, Mount St. Helens erupted violently. At 8:32 a.m. Pacific Daylight Time, a magnitude 5.1 earthquake occurred about a mile beneath the volcano, triggering a catastrophic series of events that transformed Mount St. Helens' picturesque mountain landscape into a gray wasteland.

The Catastrophic Eruption

The earthquake shook the walls of the volcano's summit crater and triggered many small rock avalanches. Within seconds, a huge slab of the volcano's north flank began to slide, and small dark clouds billowed out of the base of the slide. Plumes of steam and ash also rose from the volcano's crater. As the avalanche of rock and ice raced down the mountain's north flank at more than 250 kilometers per hour (155 miles per hour), a massive explosion blasted out of the north side of the volcano. This ***lateral blast*** became a fearsome torrent of ash and rock that outraced the avalanche. Probably no more than 20 to 30 seconds had elapsed since the triggering earthquake!

The Eruption Was No Surprise

The eruption of Mount St. Helens was not a surprise. For nearly 2 months, scientists had been monitoring changes at Mount St. Helens. For a volcano to erupt, magma must move to the Earth's surface. Increased earthquake activity, eruptions of steam and ash, and changes in the shape of the surface of the volcano all signal that magma is on the move toward the surface.

Inside the volcano, the solid rock that surrounds the molten rock often cracks from the increased pressure and causes earthquakes. Between March 20 and May 18, more than 10,000 earthquakes were recorded beneath Mount St. Helens. The largest of these were felt by people living near the volcano. In addition to recording the discrete jolts characteristic of earthquakes, ***seismographs*** also detected continuous rhythmic vibrations called ***harmonic tremors***. These numerous small earthquakes were further evidence that magma was moving within the volcano.

As magma made room for itself inside the volcano's cone, the surface of the volcano swelled, or inflated. By early April, Mount St. Helens' north flank began to visibly bulge and crack. The bulge grew 2 to 3 meters (7 to 9 feet) a day and it moved outwards about 150 meters (450 feet) in 2 months.

When the 5.1 magnitude earthquake shook Mount St. Helens on May 18, 1980, the bulge collapsed. The resulting avalanche was the largest ***volcanic avalanche*** recorded in historical times. In turn, the sudden removal of masses of rock and ice by the avalanches triggered an explosive eruption of steam trapped in cracks and voids in the volcano and of gases dissolved in the magma. Unleashed by the abrupt release of pressure, magma, rock, ash, ***aerosols***, and gases exploded from within the volcano's north flank.

The Mountain is Transformed

In a few minutes, Mount St. Helens symmetrical cone was transformed. It was 400 meters (1,312 feet) shorter and a gaping crater was gouged into its north side. An avalanche of rock, ash, ice, water, and fallen trees flowed as far as 9 kilometers (15 miles) down the valley of the North Fork Toutle River. Debris dumped into Spirit Lake raised the lakebed by more than 940 meters (295 feet). The lake's cool, crystal-clear waters became a black stew of rocks, mud, and floating trees. Gone were 70 percent of the ***glaciers*** that had crowned the volcano, melted by the heat of the eruption or carried away by the fast-moving avalanche. Towering forests with trees up to 45 meters (150 feet) were flattened and strewn like match sticks in the wake of the lateral blast and debris-laden avalanche.

Eruptions Continue

Between May 18, 1980, and October 1995, Mount St. Helens has had at least 21 eruptions of magma and dozens of smaller gas explosions. All of the volcanic activity has taken place in the bottom of the crater created by the May 18, 1980, eruption. There Mount St. Helens is rebuilding itself. During each eruption, new lava squeezes up and pushes aside old material from the surface of the ***dome***. The volcanic activity that began in 1980 is not yet over.

Activity 1 The Mountain Blows its Top

45 minutes
By observing **two demonstrations**, students will understand (1) why a bulge developed on the north flank of Mount St. Helens and (2) why the avalanche triggered an explosive eruption.

Key teaching points

1. The bulge that developed on the north flank of Mount St. Helens was evidence of changes occurring inside the volcano. Magma was moving closer to the surface and inflating, or deforming, the side of the volcano.

2. Scientists had been closely monitoring the growth of the bulge for nearly a month to help them try to forecast an eruption.

3. The 5.1 magnitude earthquake on May 18, 1980, shook the volcano, including the bulge area. In turn, the shaking of the bulge area caused a sudden collapse of the volcano's north flank and triggered a large avalanche.

4. The removal of this large mass of rock by the avalanche caused a sudden release of pressure inside the volcano and a violent eruption occurred.

Materials

1. 1,500 ml beaker (Pyrex™)
2. Damp sand
3. Several small balloons
4. Rubber bands
5. Bunsen burner or hot plate
6. Straight pin
7. A bottle of soda water
8. Basin or bowl to catch the "explosion"
9.. Master Sheet 2.1

Procedures

Preparation

Before class begins, put about ½ inch of sand in the bottom of the beaker and level the surface of the sand. Partially inflate a balloon, secure it with a rubber band, and place the balloon on top of the sand in the beaker. Cover the balloon with sand to a depth of about 1½ inches. Level the surface of the sand.

Introduction

In class begin the lesson by reviewing **the series of events** that occurred on May 18, 1980. Use Master Sheet 2.1 to discuss the following events: the **bulge** that had been growing on the north side of the volcano for a month, the 5.1 magnitude **earthquake** that triggered an **avalanche**, and the avalanche that unleashed an explosive eruption, a **lateral blast**.

Demonstration 1:
Why the bulge grew

1. Partially inflate a balloon. Ask students what would happen to the balloon if you were to heat the air in the balloon? (The balloon would expand because the air expanded.) Explain that inflation caused a bulge to develop on the north flank (side) of Mount St. Helens.

2. Tell the students that the inflated balloon represents the magma rising within Mount St. Helens and that the sand represents the surface of Mount St. Helens. (*fig. 1)*

3. Show the beaker to the students and tell them you have a partially inflated balloon in the beaker. Place the beaker on the Bunsen burner or the hot plate. Heat the beaker until the balloon begins to expand. (The surface of the sand should begin to "bulge".) (*fig.* 2)

4. Observe the changes in the shape of the surface of the sand. What happens to the "land" as the "magma chamber" expands?

Demonstration 2:
Why the avalanche triggered the explosive eruption

1. Ask students what would happen if you were to stick a pin into the balloon. (It would pop or explode.) Why does it explode? Burst the balloon. (The balloon bursts because the pressure inside the balloon is suddenly released and the gases can escape rapidly.)

2. Ask students what happens when they open a bottle of soda. (It goes "fizz" because the gas, CO_2, in the soda escapes.) Demonstrate this by shaking a bottle of soda water and releasing the cap. (The soda water "erupts" out of the bottle.)

3. Return to the the poster (*poster fig.1*). Compare the soda bottle to a magma chamber. As long as the top is on the bottle, there is no eruption. Compare the rock and ice that was unloaded by the avalanche to the soda cap. When the "cap" was suddenly removed, the pressure inside the volcano was suddenly released, and the volcano erupted.

fig. 1

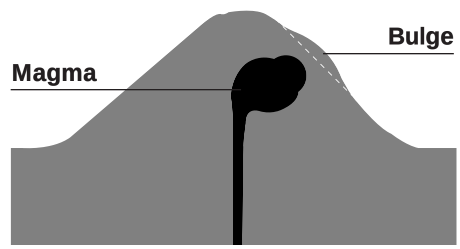
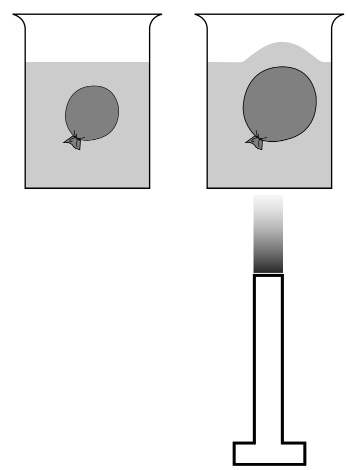


fig. 2



Activity 2 Mapping Mount St. Helens

30-minute demonstration
45-minute work session

Students use ***topographic map*** skills to interpret the impact of the May 18, 1980, eruption of Mount St. Helens on the volcano's topography.

This activity is divided into an **introduction, a demonstration,** and **a student work session.**

In the **demonstration** you (1) introduce students to topographic maps and contour lines and (2) construct a simple three-dimensional model of Mount St. Helens before the May 18, 1980, eruption.

In the **work session**, students draw ***profile views*** of Mount St. Helens before and after the May 18, 1980, eruption. Students use these profiles to interpret the changes in the mountain's topography that were caused by the eruption.

Key teaching points

1. Because volcanic eruptions both create and destroy landforms, they cause changes on the surface of the Earth's lithosphere. The May 18, 1980, eruption of Mount St. Helens destroyed a significant portion of the mountain that had been created by previous eruptions.

2. Within a few minutes of the start of the eruption, the mountain lost 400 meters (1,312 feet) of its height and a gaping crater 625 meters (2,050 feet) deep, 1.7 miles (2.7 kilometers) long, and 1.3 miles (2 kilometers) wide opened on its once nearly symmetrical cone.

3. The changes to Mount St. Helens' landscape have been recorded on topographic maps. Topographic maps represent the three-dimensional features of a landscape on a two-dimensional surface.

Materials

1. Master Sheet 2.2
2. Play-doh®
3. Scissors
4. Activity Sheet 2.1 (2 sheets)

Procedures

Introduction

1. Begin this activity by showing the class the photograph on the poster of Mount St. Helens taken before the 1980 eruptions (*poster fig. 10*).

2. Remind students that Mount St. Helens began erupting about 40,000 years ago, but most of its height formed over the past 2,500 years from repeated eruptions. At the time of the May 18, 1980 eruption it was 2,780 meters (9,677 feet) high. Some eruptions can destroy part of the mountain that earlier eruptions have built.

3. Look at the photograph (*poster fig. 11*) taken after the May 18, 1980 eruption. Ask students what they think the impact of the May 18, 1980 eruption was on the shape and size of Mount St. Helens.

4. Tell students that they will use topographic maps of Mount St. Helens before and after the May 18, 1980 eruption to verify or refute their observations.

5. Use a transparency of Master Sheet 2.2 to explain that a topographic map shows topography — the highs and lows of a given area.

- Topographic maps use special lines called ***contour lines*** to show the shape and elevation of the land.
- On this map, each contour line represents 100 meters (330 feet) change in elevation.
- With your finger trace the "2,000" meters contour line.
- Tell students that if they were walking on this imaginary line, they would never go up or down. To walk up or walk down, they would have to change lines—much like walking up or down steps.

Demonstration:
A profile model of Mount St. Helens before the 1980 eruption.

1. Make a transparency and 4 photocopies of Master Sheet 2.2 (topographic map of Mount St. Helens before the 1980 eruptions).

2. Use the transparency to show students the topographic map of Mount St. Helens before the 1980 eruptions.

3. Tell your students that you will use this topographic map to " build" Mount St. Helens before the 1980 eruptions. (*fig. 3)*

4. Cut along the 1,400 meters contour line to make a pattern. Roll out Play-doh® about ½ inch thick and place the cutout on top of the Play-doh®. With a sharp point, trace along the contour line to form your first layer.

5. Cut along the 1,600 meters contour line to make a second pattern. Roll out Play-Doh® about ½ inch thick, place the pattern on top of it, and trace along the contour line to make your second layer. Stack layer 2 on top of layer 1, like building a tiered wedding cake.

Using Topographic Maps

Topographic maps use contour lines, which are imaginary lines that connect all points at the same elevation. By reading these lines, you generally can tell: (1) the elevation of the land, (2) the steepness of a slope, and (3) the shape of the land.

— **Contour lines are always parallel. They never cross.**

— **The closer together the contour lines, the steeper the slope.**

— **Closed depressions, such as a volcanic crater, are marked with short lines pointing downslope.**

— **Every fifth contour line is made heavier and the elevation is always marked. (This makes contours easier to read and count.)**

Activity 2 Continued

fig. 3

6. Repeat this process for the 1,800, 2,000, 2,200, 2,400, 2,600, and 2,800 meters contour lines.

7. Give students an opportunity to look at the model. Have them pay special attention to the side view, or profile, as a preparation for their work session.

Work session: Drawing profile maps

1. Hand out Activity Sheets 2.1. Map A is a topographic map of Mount St. Helens before the 1980 eruptions. Map B is a topographic map of Mount St. Helens after the eruptions.

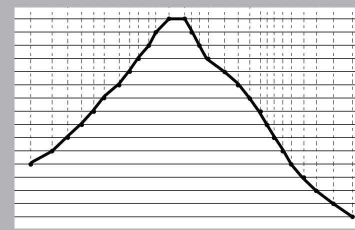
2. Following the directions on their Activity Sheets, students use topographic maps to draw a profile (side view) of Mount St. Helens before and after the 1980 eruptions.

3. Students compare the completed profiles to see how the eruption changed the size and shape of Mount St. Helens.

4. As a class, calculate how many meters in elevation Mount St. Helens lost as a result of the May 18, 1980, eruption. (400 meters/1,312 feet)

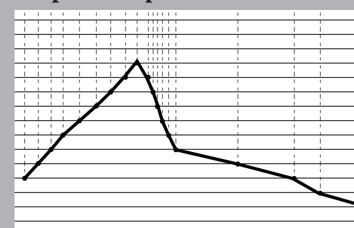
Activity Sheet 2 Answers

Map A completed



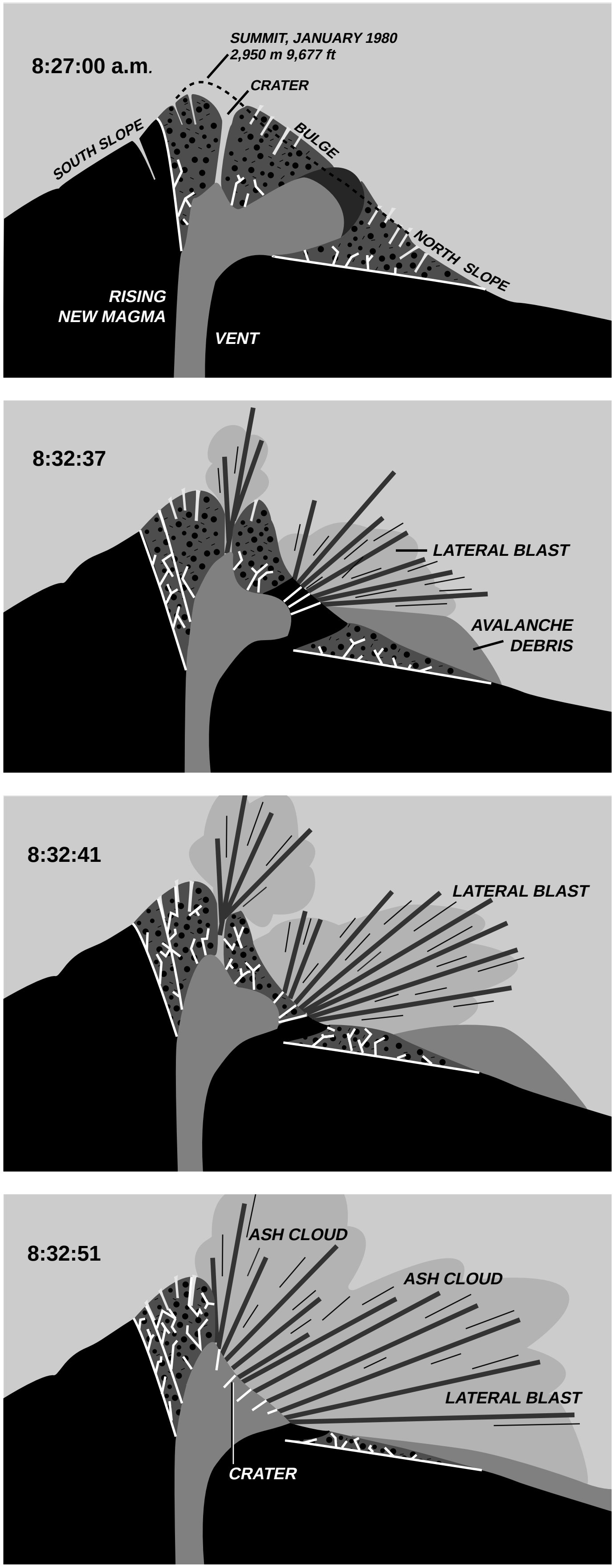
1. Cone shape; mountain-like
2. 2,800

Map B completed

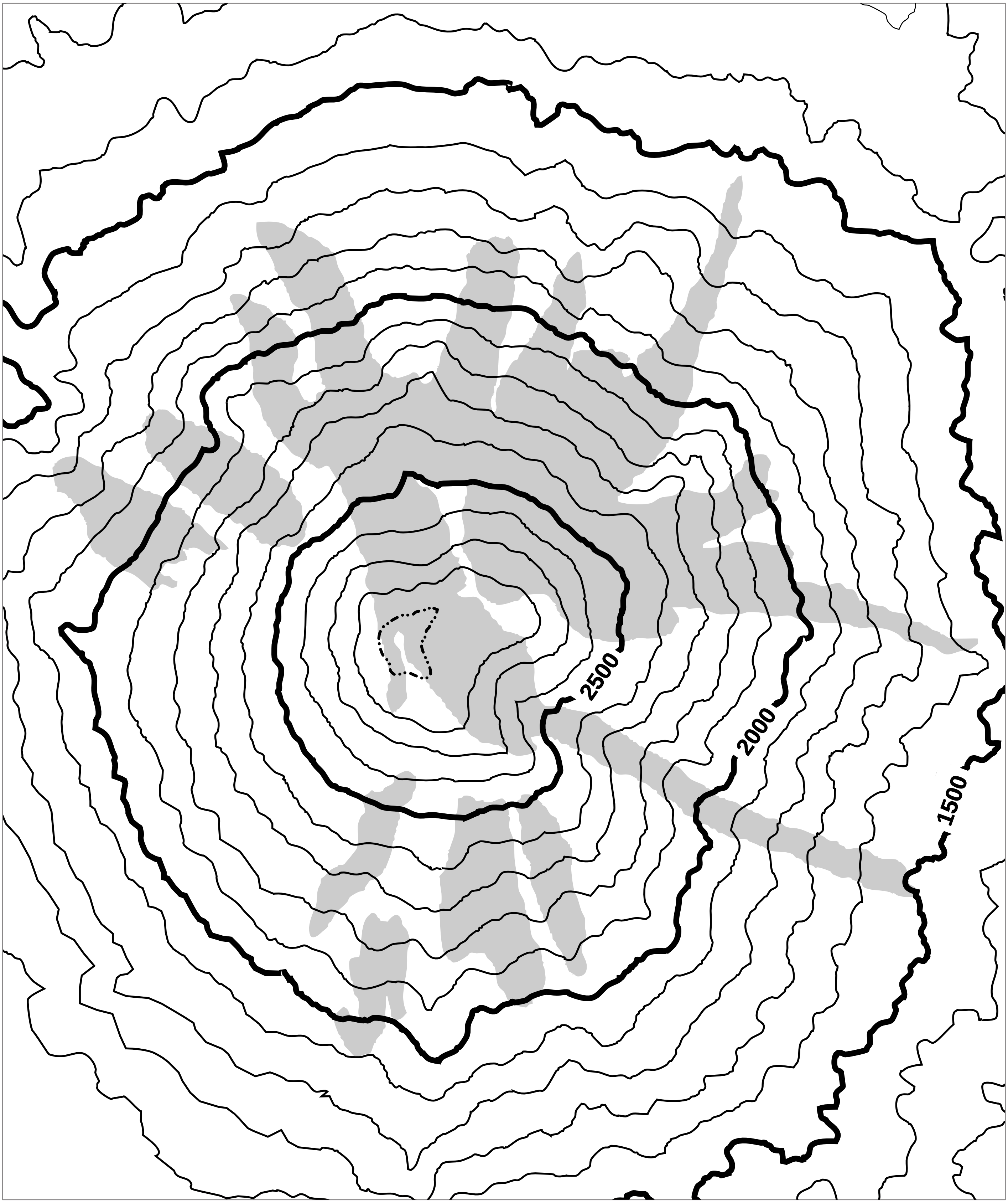


5. Yes. Part is missing. It is no longer a cone.
6. About 2,400 meters
7. Lower
8. Bigger

Master Sheet 2.1



Master Sheet 2.2



Legend

0 1 km

Contour interval
100 meters

Glaciers

Crater

N

VOLCANOES!

Activity Sheet 2.1Map A
The Mountain Blows its Top

These are topographic maps of Mount St. Helens. Map A is Mount St. Helens before the 1980 eruptions and Map B is Mount St. Helens after the May 18, 1980, eruption. Compare these maps and you will see how the eruption changed the size and shape of Mount St. Helens.

What do Topographic Maps Show?

Topographic maps show the shape and elevation of the land by using special lines called *contour lines.* A contour line is an imaginary line that connects points at the same elevation, or height. Elevation is how high, or low, the land is above sea level. Sea level is "0" meters. On these two maps, each contour line equals a 100 meters (330 feet) change in elevation. To make the lines easier to read, every 500 meters (1,550 feet) is shown in a heavy black line.

Map A: Before the Eruption

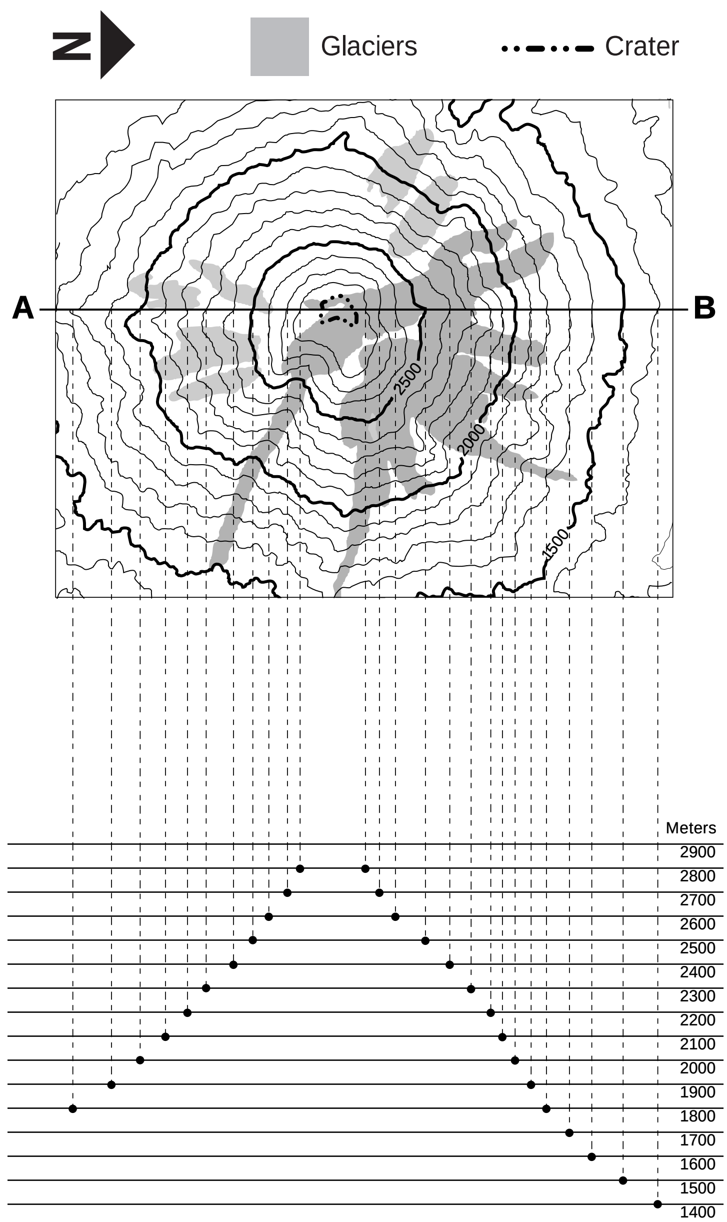
The top of this drawing is a topographic map of Mount St. Helens before the 1980 eruption. It shows the volcano's shape and elevation as if you were looking at the volcano from the air. The bottom of this drawing is a profile view. It shows the volcano's shape and elevation from the side.

What to do

1. On the bottom illustration, connect the dots. What shape have you drawn?

---

2. Find the highest point on the bottom illustration, put an "X" there. To find the approximate elevation, trace your finger across to the numbers on the left side. That number is about ___________ meters.



VOLCANOES!

Activity Sheet 2.1Map B
The Mountain Blows its Top

Map B: After the Eruption

The top of this drawing is a topographic map of Mount St. Helens after the May 18, 1980, eruption. You will draw a profile view at the bottom to see how the shape and elevation of the volcano changed after the eruption.

What to do

1. Find the contour lines on the topographic map. Trace your finger around the 2,000 meters contour line.

2. Draw a line between the letter "A" and the letter "B." This line cuts across the top of the volcano.

3. Starting from "A" trace across the line until you cross a contour line. At that point, draw a line down to the chart below until you find the same number. Put a •. Repeat until you get all the way across line A——B. We have done the first few for you.

4. Connect all the dots.

5. Has the shape of the volcano changed? How?

____

____

____

6. Find the highest point. How many meters high is the volcano?

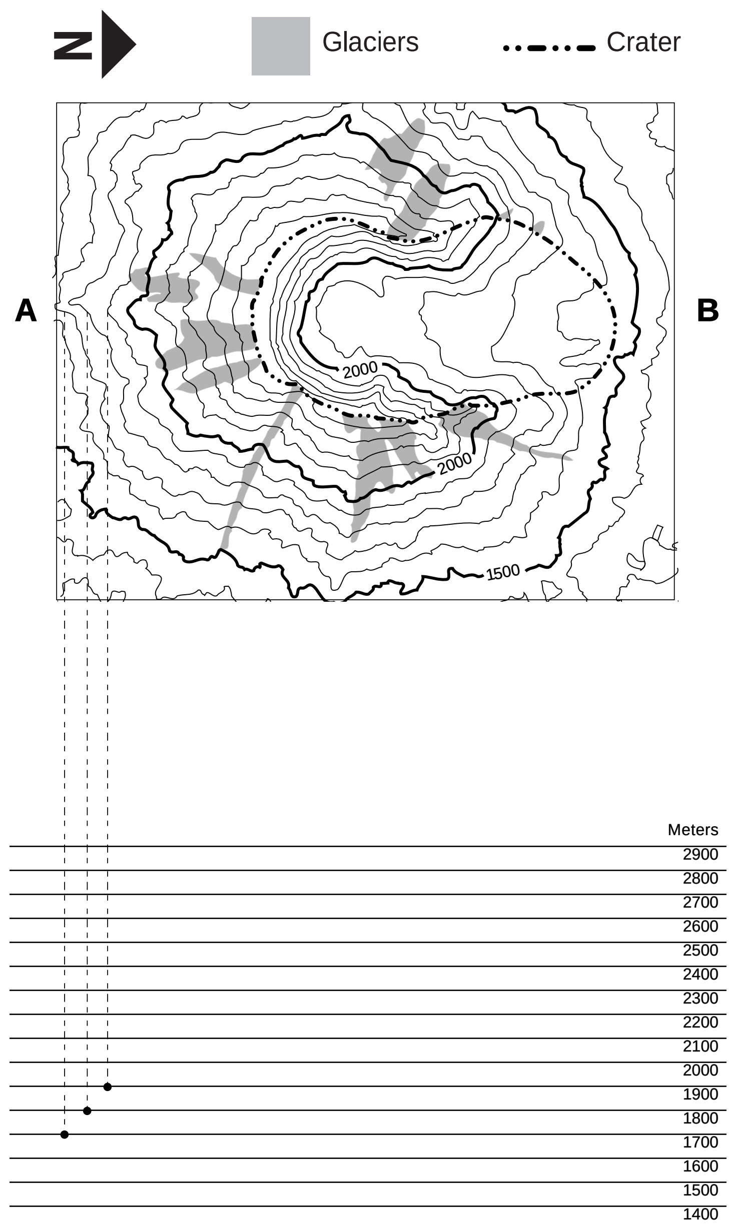
____

7. Is the volcano higher or lower than before the eruption?

____

8. Find the crater. Is it bigger or smaller than before the eruption?

____



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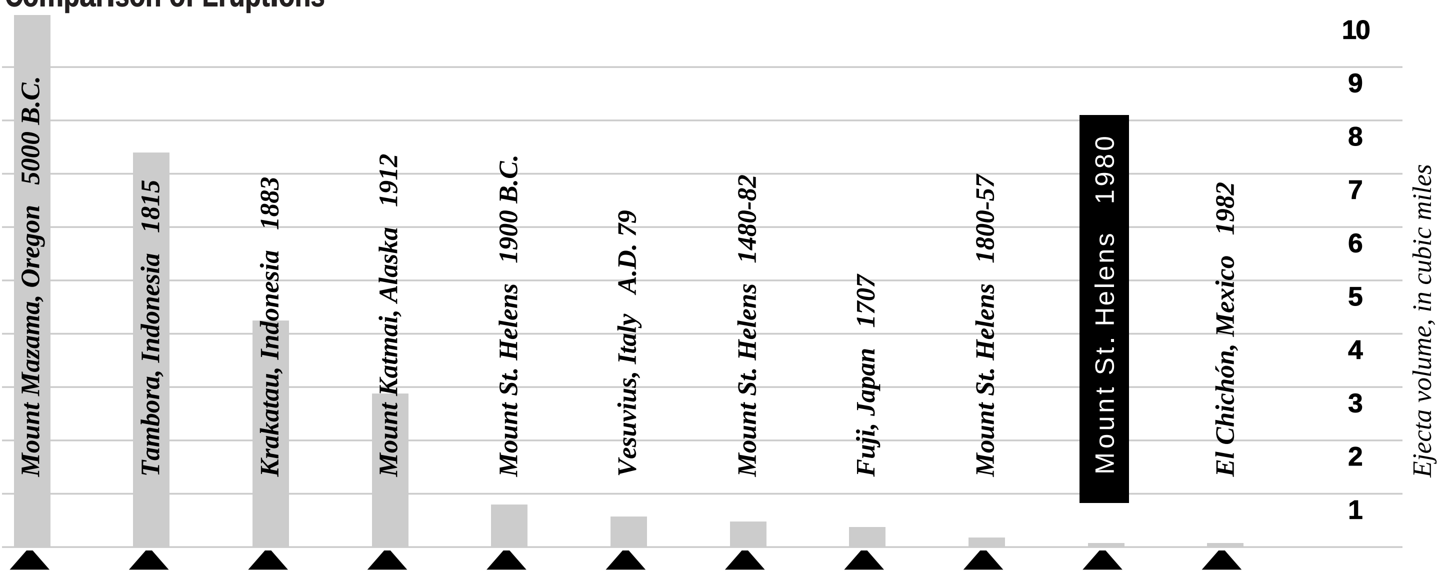
VOLCANOES! UP IN THE AIR

LESSON 3

fig. 1

Comparison of Eruptions



The volume of ash ejected during an eruption is one factor in measuring the size of an eruption. Note that the May 18 volume was less than several earlier eruptions of Mount St Helens and considerably less than eruptions of other volcanoes.

In less than 10 minutes after the onset of the cataclysmic eruption of Mount St. Helens, a column of ***tephra***, steam, ***aerosols***, and gases reached an altitude of 19 kilometers (12 miles). Although the largest fragments of tephra fell back to the ground close to the volcano, the smallest fragments, ***ash*** and dust, were carried eastward by the ***prevailing winds***. Five days after the eruption, monitoring instruments in New England detected ash from Mount St. Helens. Some of the ash eventually circled the globe and the smallest fragments and aerosols remained suspended for years in the ***stratosphere.***

Day Becomes Night

Moving at an average speed of 95 kilometers per hour (60 miles per hour), the ash cloud reached Yakima, Wash., by 9:45 a.m. Pacific Daylight Time and Spokane, Wash., about 2 hours later. In Yakima, a city of 51,000, day became night. Automobile and street lights remained on for the rest of the day as the eruption continued for more than 9 hours. Ash as fine as talcum powder clogged engine air filters and choked people—face masks or handkerchiefs were a necessity for those who ventured out of doors.

Ash blanketed the ground like snow, but snow that would not melt. Residents shoveled and bulldozed ash from streets, sidewalks, and roofs; an estimated 600,000 tons of ash were removed from the city. It took 10 weeks to haul it away!

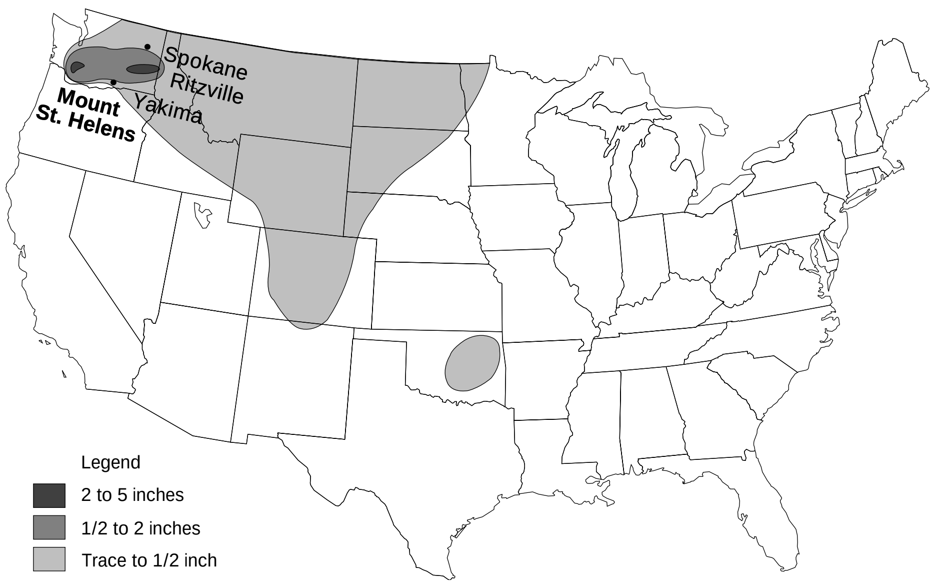
Volcanic Ash's Deadly Effects

Ash fall, however, is more than an inconvenience. It can be lethal to plants, wildlife, and humans. Swirling particles of ash in the atmosphere generated lightning, which in turn ignited hundreds of forest fires near the volcano. Autopsies revealed that most of the human deaths in the blast area resulted from asphyxiation, from inhaling hot volcanic ash during the first few minutes of the eruption.

As the ash settled to the ground, it also took its toll. Eastern Washington became known as the "ash belt" where many farm crops were destroyed in areas of thick accumulation. Volcanic ash can also affect aircraft operations. Jet engines are susceptible to damage: the volcanic ash coats and melts turbine blades, often causing the engines to stall.

Activity 1
Tracking an Ash Cloud

fig. 2



This map shows the distribution of ash fallout from the May 18, 1980, eruption.

Impact on Climate

Volcanic eruptions can also affect climate and weather patterns. Mount St. Helens' 1980 eruptions did not have a significant effect on global climate, but the 1982 eruption of El Chichòn in Mexico, for example, had measurable effects. El Chichòn's magma was much richer in sulfur than Mount St. Helens'. As a result, the Mexican volcano produced sulfuric acid aerosols (a fine mist of particles) that formed a layer of haze in the stratosphere. This haze, which can remain in the atmosphere for years, reflects the sun's radiation and reduces surface temperatures. For example, more than a year after the April 1815 eruption of Indonesia's Tambora volcano, its effects were felt. In the northeastern United States, 1816 was so cold that snow fell in some New England States in June and July. It was known in New England as the "year without a summer."

How Much Ash Fell?

In comparison to other historic eruptions, the volume of ash fall from the 1980 eruption of Mount St. Helens was relatively small (*fig. 1*). The eruption of Tambora ejected 150 times more ash than Mount St. Helens in 1980. And ash ejected by Mount Mazama (now Crater Lake), located about 125 kilometers (200 miles) south of Mount St. Helens, was even greater than Tambora. The 1980 eruption of Mount St. Helens was only an inkling of the destructive potential of a volcanic eruption.

15-minute demonstration
45-minute work session

Students observe a **demonstration** of a "dust box" to help them understand that some volcanic ash (tephra) may be difficult to see. In a **work session**, they will then use the equation, D = RxT (*distance* is equal to the *rate* of speed times the *time* of travel) to calculate the time it took volcanic ash erupted into the atmosphere to travel to different parts of the United States following the May 18, 1980, eruption of Mount St. Helens.

Key teaching points

1. Explosive volcanoes can erupt large quantities of tephra, gases, and aerosols into the atmosphere.

2. The smallest of these particles are suspended in the atmosphere and are sometimes carried by wind great distances from the immediate site of an eruption. Some of these particles are too small to see.

Materials

Demonstration

1. Large cardboard box such as a photocopy paper box
2. Black construction paper, dark cloth bed sheet, or black spray paint
3. Glue, tape, or staples
4. Scissors
5. Pencil or pen
6. Flashlight
7. Two erasers with chalk dust

Work Session

1. Activity Sheets 3.1a–b
2. Atlas
3. Colored pens or pencils
4. Calculators (optional)

Procedures

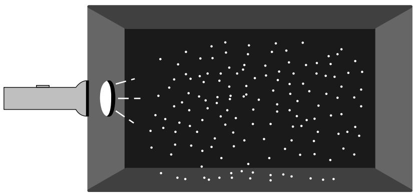
Preparation:
Assembling the "dust box" *(fig. 3)*

1. Remove the flaps from one side of the box.

2. Line the interior of the box with black construction paper or a dark sheet, or spray paint it black.

fig. 3

“Dust Box”



3. On one side, cut a hole the same size as the lamp end of the flashlight.

Introduction

Use *side 1 of the poster* and point out the column of ***ash*** rising above Mount St. Helens. Remind students that in Lesson 1 they learned that explosive volcanoes like Mount St. Helens erupt rock and lava fragments, gases, and aerosols into the atmosphere. The rock fragments, which are called tephra, can range in size from car-sized boulders to ash or dust that is so small it is invisible to the naked eye.

Demonstration

1. With the lights on, beat two erasers together inside of the “dust box.”

2. Ask students to raise their hands when they can no longer see any “dust” in the air. When the last student has raised his or her hand, turn on the flashlight. Ask students to put their hands down if they now see dust.

Work Session

1. Discuss the photographs and captions in the atmosphere section of the poster (*poster figs. 12–14.*). Remind students of the “dust box” demonstration. Like chalk dust, the smallest volcanic particles stay suspended in the atmosphere. Once in the atmosphere, they can be carried by wind great distances from the volcano. (*fig. 2*)

2. Some of these particles are so small that they form invisible clouds, which are particularly dangerous to airplanes that unknowingly encounter volcanic ash clouds. Volcanic ash sucked into jet engines can cause the engines to stall, as the following story illustrates:

Following the 1989 eruption of Mount Redoubt in Alaska, a Boeing 747 aircraft lost power in all four of its engines after flying into a volcanic ash cloud. Finally after losing 4,267 meters (14,000 feet) in altitude the pilot was able to restart the engines. The airliner landed safely, but the damage to the aircraft has been estimated to exceed $80 million. Because of the potential hazard posed by ash clouds to aircraft, air traffic controllers need to issue warnings to aircraft flying in the air space they monitor.

3. Tell the students that they are air traffic controllers. They have just received word that Mount St. Helens has had a major eruption. They should stand by to receive critical data so that they can calculate when airborne ash will reach the air space they monitor. Discuss with the class the type of data they will need to gather, such as

- the time of the eruption,
- the wind direction,
- the rate of speed the airborne tephra is traveling, and
- how far their city is located from the eruption.

4. Divide the class into teams of air traffic controllers for each of the following locations:

- Great Falls, Mont.
- Rapid City, S. Dak.
- Madison, Wis.
- Minneapolis, Minn.
- Chicago, Ill.
- Detroit, Mich.
- Pittsburgh, Pa.
- Boston, Mass.

5. On their activity sheet, each team will use the data to calculate the time the ash is expected to arrive in the air space they monitor. (The ash cloud is moving at a rate of 96 kilometers per hour.)

6. Distribute the Activity Sheets.

7. Before students begin, review with the class the formula (D=RT). Demonstrate how to use the formula to calculate both rate and time.

8. As a homework assignment, ask each student to calculate the time it took the

ash cloud to circle the Earth. The Earth is 40,000 kilometers (20,500 miles) at the Equator.

Activity Sheet 1
Answers

City	Kilometers	Hours
Great Falls	850	9
Rapid City	1,450	16
Madison	2,500	27
Minneapolis	2,100	23
Chicago	2,700	29
Detroit	3,050	33
Pittsburg	3,400	37
Boston	3,900	42

Activity 2 In the Rain Shadow

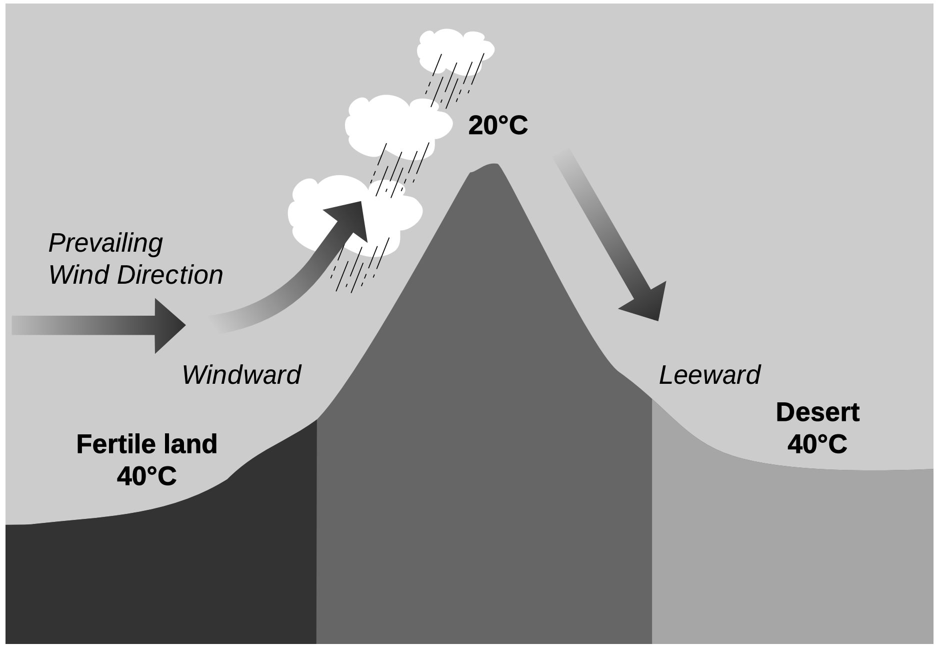
45 minutes
By recording the annual precipitation (rain and snow) for cities on the east and west sides of the Cascade Mountains, students will discover that volcanic mountains do not have to erupt to affect the atmosphere.

Key Teaching Points

1. The Cascade Range comprises a 1,130-kilometers (about 700 miles) long chain of volcanoes lying about 160 to 240 kilometers (100 to 150 miles) inland from the coast of the Pacific Ocean. Their location affects the climate of the Pacific Northwest region.

2. Because the Cascades act as a geographic barrier to moisture-laden masses of air arriving from the Pacific Ocean, cities on the west side of the mountain receive more precipitation annually than those on the east side. The cities on the east side are in the "rain shadow" created by the mountains.

fig. 4



The windward side of a mountain receives a higher annual precipitation than the leeward side.

Materials

1. Activity Sheets 3.2 a–b
2. Wall map of the United States
3. Glass of ice water

Procedures

1. Using a large wall map, locate the Cascade Range. Remind students that Mount St. Helens is one of the volcanic mountains that make up the Cascade Range.

2. Tell students that in the Pacific Northwest region, the ***prevailing winds*** blow from west to east. That means that most of the weather that affects the region forms over the Pacific Ocean where it picks up a great deal of moisture. Given this fact, ask students if they think annual precipitation is greater or lesser on the west or east side of the mountains.

3. Distribute Activity Sheets 3.2 a–b.

4. After the students have completed their activity sheets, discuss with them the reasons why cities on the west side of the Cascade Range have a greater precipitation than those on the east side of the mountains.

- The mountains act as a barrier: Air must rise to get over the mountains. As the air rises, the temperature of the air falls and moisture in the air condenses. As the moisture condenses, it falls as rain or snow. By the time the air reaches the top of the mountain, most of the moisture has been lost as rain or snow.
- As the air descends on the other side of the mountain, most of the moisture that remains is lost through evaporation instead of falling as precipitation.
- That is why cities on the western, or ***windward***, side of the Cascades receive a higher annual precipitation than those on the eastern, or ***leeward***, side of the Cascades. The mountains have produced a "rain shadow" on the leeward side (*fig. 4*).

Extension

Have students prepare reports discussing how the differences in precipitation in the Pacific Northwest affect the natural resources and economy of the region.

Activity Sheet 2 Answers

3.

Western	**Eastern**
Eugene	Burns
Olympia	Pendleton
Portland	Spokane
Salem	Walla Walla
Seattle	Yakima
Tacoma	

4. Western average precipitation: 162 centimeters
Eastern average precipitation: 52 centimeters

5. The cities on the west side receive more precipitation

VOLCANOES!

Activity Sheet 3.1a
Tracking an Ash Cloud

Volcanic ash can be a serious hazard to jet airplanes when they are flying. Because pilots may not see volcanic ash clouds, they can fly into them. When ash is sucked into a jet engine, it can cause the engine to stall.

Fortunately, when this has occurred, the pilots were able to restart their engines, but only after losing many thousands of meters in altitude.

You are air traffic controllers and you have just received a warning that there was a major eruption of Mount St. Helens this morning. The air space you monitor is in the path of an ash cloud. Your job is to calculate approximately how many hours it will take the ash cloud to move into the air space you monitor. **The warning notice states that the ash cloud is moving at a rate of 96 kilometers per hour (60 miles per hour).**

Knowing how fast the ash cloud is moving, **your job is to calculate approximately how many hours (the time) it will take the ash cloud to reach your air traffic control tower.**

What to do

List the following information:

1. On the map, find the location of your tower:
   Mark it on the map.

2. Find Mount St. Helens. Mark it on the map.

3. Look at the map legend. Calculate the number of kilometers (distance) your tower is from Mount St. Helens.
   My tower is________ kilometers from Mount St. Helens.

4. Use this formula to find how many hours (time) it will take the ash cloud to reach your tower.

Distance

$$\frac{D}{R \times T}$$

Rate (speed) x **T**ime

5. The ash cloud will reach your air traffic control tower in ________ hours.

Activity Sheet 3.1b
Tracking an Ash Cloud

VOLCANOES!

Activity Sheet 3.2a
In the Rain Shadow

Mount St. Helens is one of the volcanic mountains that make up the Cascade Range. The Cascade Range is about 1,130 kilometers (700 miles) long. It is located about 160 to 240 kilometers (100 to 150 miles) inland from the coast of the Pacific Ocean. The location of the mountains affects the climate in the Pacific Northwest. Cities located on the western side of the mountains receive different amounts of precipitation (rain and snow) than cities located on the eastern side of the mountains.

What to do

1. On the map, the symbol ▲ marks a volcanic mountain in the Cascade Range. Find each of the volcanoes listed below. Then, on the map draw a line connecting all the ▲ symbols. The line you have drawn will show you the approximate location of the Cascade Range.

Mt. Adams	Mt. Jefferson
Mt. Baker	Lassen Peak
Glacier Peak	Mt. Rainier
Mt. Hood	Mt. Shasta
	Mount St. Helens

2. On the map, find the **west** side of the Cascade Range and write the letter **"W."** Then find the **east** side of the Cascade Range and write the letter **"E."** (Hint: the Pacific Ocean is to the west of the Cascade Range.)

3. On the map, each of the following cities is marked with the symbol ●.

Name	Annual Precipitation
Burns, Oreg.	47 centimeters (12 inches)
Eugene, Oreg.	169 centimeters (43 inches)
Olympia, Wash.	201 centimeters (51 inches)
Pendelton, Oreg.	47 centimeters (12 inches)
Portland, Oreg.	146 centimeters (37 inches)
Salem, Oreg.	158 centimeters (40 inches)
Seattle, Wash.	154 centimeters (39 inches)
Spokane, Wash.	71 centimeters (18 inches)
Tacoma, Wash.	146 centimeters (37 inches)
Walla Walla, Wash.	62 centimeters (16 inches)
Yakima, Wash.	32 centimeters (8 inches)

Find each city on the map. Is it **east** or **west** of the Cascade Range? On the chart below, list each city in either the "Eastern Cities" or "Western Cities" column and write in the annual precipitation for each city.

Western Cities	Eastern Cities
______________________	______________________
______________________	______________________
______________________	______________________
______________________	______________________
______________________	______________________
______________________	______________________
______________________	______________________
______________________	______________________
______________________	______________________
______________________	______________________

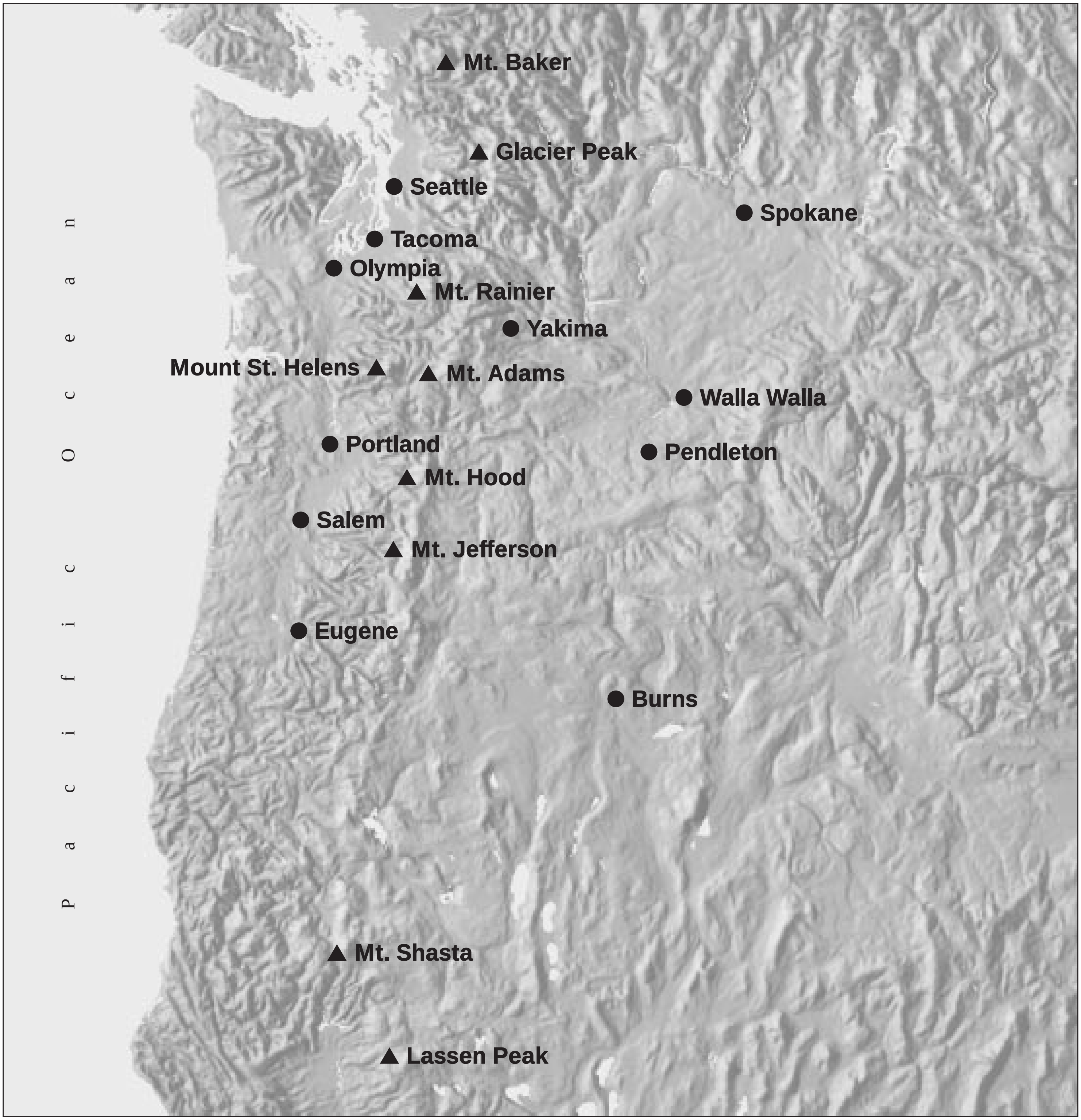
4. Find the average amount of precipitation that the "Eastern Cities" get and the "Western Cities" get.

   Average precipitation for "Eastern Cities": ____________

   Average precipitation for "Western Cities": ____________

5. Do cities on the east or west side of the Cascade Range receive more precipitation? ____________

Activity Sheet 3.2b
In the Rain Shadow



Legend

0 200 km

▲ Volcanic Mountains

● Cities

N

Activity 1 Forecasting the Path of Mudflows

30-minute demonstration
45-minute work session

Students participate in a **demonstration** that will help them visualize the consistency of mudflows and how they move down stream valleys away from a volcano's summit or flanks. In a **work session**, students use topographic maps of Mount St. Helens before the 1980 eruptions to forecast the path mudflows might take during an eruption.

Key teaching points

1. Volcanic avalanches and volcanic mudflows are somewhat similar, but different in one important respect. Both can contain (a) volcanic debris, such as tephra of varying sizes ejected during an ongoing eruption, and (b) lava and rocks from previous eruptions that were deposited on the volcano's slopes. Mudflows, however, are mixtures of volcanic debris and water. Volcanic avalanches lack the water of mudflows.

2. Sources of water can include the (a) breakout of a volcanic or glacial lake, (b) melting snow and glacier ice, (c) streams and rivers that flow down the flanks of a volcano, and (d) intense rainfall.

3. Mudflows behave differently than avalanches. Because water acts as a lubricant, mudflows travel farther than avalanches. Both avalanches and mudflows can move very fast.

4. Mudflows move downslope and into stream valleys.

5. Being able to forecast the path of mudflows is important to scientists who assess the potential hazards of volcanic eruptions. The chief threat to people is burial. Structures are at risk of being buried, carried away, or collapsing.

Materials

Demonstration

1. Newspapers
2. Large plastic tarp, 9' x 12'
3. Rocks, bricks, or tent stakes to hold the tarp in place
4. Buckets
5. Large spoons or other sturdy stirring instruments
6. One paper cup for each student
7. Sand and gravel
8. Water

Work Session

1. Activity Sheet 4.1a-b
2. Transparencies made from Master Sheet 4.1 and Activity Sheet 4.1b.
3. Overhead projector

Procedures: Simulating an avalanche and mudflow

1. Outdoors, construct a mockup of a volcano by crumbling up newspapers and piling them into the shape of a volcano.

2. Place a tarp over the newspapers. Make sure the tarp is large enough to simulate a flat area at the volcano's base. Also, create plenty of "hills" and "valleys." For ideas, refer to the photographs on the poster and to the topographic map on Activity Sheet 4.1b.

3. Place bricks, rocks, or tent stakes around the base of the tarp to keep it from moving.

4. Tell students that they will be creating an avalanche. Ask them to forecast the path the avalanche will take.

5. Create an avalanche:

- Distribute paper cups and fill them with sand.
- Pour the contents onto the top of the volcano to simulate an avalanche.
- Repeat with gravel and then again with a mixture of sand and gravel.
- Have students observe where the materials slide and which particles move fastest.
- Discuss why. (Gravity pulls the materials downslope. The heaviest particles move fastest; the smallest particles move the farthest because they require less energy to move them.)

6. Create a mudflow:

- In a bucket, mix water with sand and gravel to make a slurry.
- Distribute paper cups and fill them with the slurry.
- Pour the slurry onto the top of the volcano.
- Discuss: Where did the mudflow flow? (It should go into the valleys.) Did it behave differently than the avalanche? What happens when the avalanche hits the flat area at the base of the volcano? (Slows down)

Work Session: Forecasting the path of mudflows

Based on what they saw in the demonstration, students use a topographic map of Mount St. Helens before the 1980 eruption to forecast the paths mudflows might take as a result of an eruption. The students then compare their maps with the map that shows the path the flows actually took following the May 18, 1980, eruption. (Master Sheet 4.1)

Distribute Activity Sheets 4.1a-b. Note that the topographic map on Activity Sheet 4.1b is the same as Map A in Lesson 2 except that it (a) covers a more extensive area, (b) the contour interval is 150 meters instead of 100 meters, and (c) north is oriented toward the top of the map.

Discussion

1. Discuss the students' forecasts. Will mudflows follow stream valleys? Will mudflows occur on all sides of the volcano?

2. Show students a transparency of Master Sheet 4.1. Compare this map with the students' forecast maps.

3. Discuss why the south flank and the area to the south were relatively untouched by mudflows. (The lateral blast blew hot volcanic debris to the north.)

4. Using your transparencies, compare the extent of the glaciers on Mount St. Helens before and after the eruption. What happened to the glaciers? What happened to the ice in the glaciers? (It was melted by the heat of the eruption or was "ground up" by the avalanche)

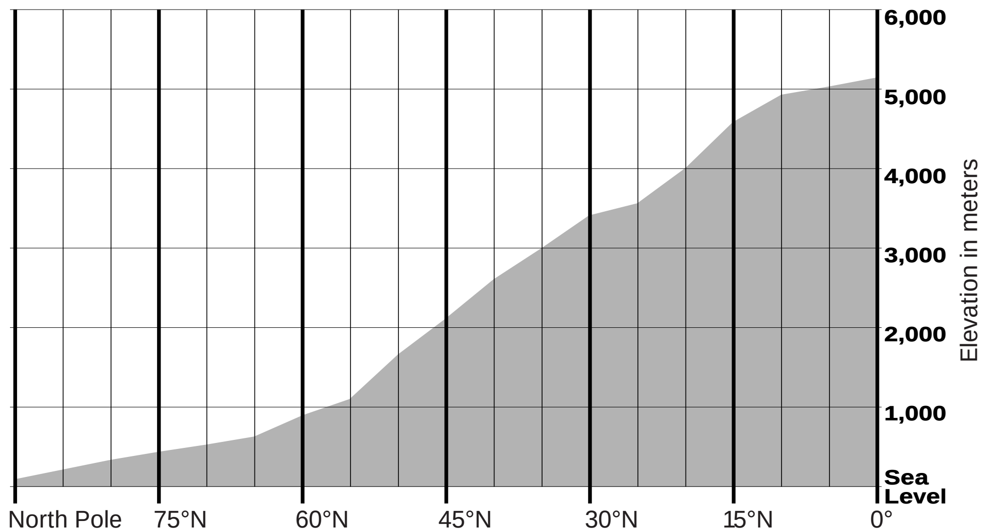
5. Bring up the point that Mount St. Helens behaved in an unexpected way

Activity 2 The Dangers of Snow and Ice

that even the scientists did not anticipate. (For example, David A. Johnston, a USGS volcanologist, was monitoring Mount St. Helens on a ridge north of the volcano, well outside of the anticipated danger zone, or so he thought. At 8:30 a.m. on May 18, 1980, Dr. Johnston made his last radio transmission: "Vancouver, Vancouver, this is it!" No trace of him or his equipment has ever been found.)

fig. 2

The Snowline



This diagram shows how the elevation of the snowline changes with latitude. The approximate elevation of the snowline is indicated on this diagram where the white and black areas meet.

45-minute demonstration
45-minute work session

Students observe a **demonstration** of how melting snow and ice can contribute to mudflows and then learn in a **work session** why some volcanic mountains have permanent snow and ice.

Key teaching points

1. Some volcanic mountains have permanent snowpacks—snow that does not melt during the summer months. The lowest elevation at which snow remains on a mountain during the summer is called the ***snowline***. (A mountain that has no snow in the summer has no snowline.) The snowline moves up and down a mountain seasonally—lowest in late winter and highest in late summer.

2. The snowline is related to air temperature, which in turn is influenced by elevation and distance from the Equator: air temperature drops as elevation increases and distance from the Equator increases. Even in areas near the Equator, there are some mountains that have snow year-round at their highest elevations, whereas in polar regions permanent snow can be found close to sea level during the summer months.

3. The snowline is highest—that is, less of the mountain is covered with snow in the summer—on mountains closest to the Equator. The snowline is lowest on land closest to the poles. The greater the distance from the Equator, the less elevation is necessary to establish a snowline. (*fig. 2*)

4. The snowline also is influenced by the amount of yearly snow fall. Thus, the snowline may not be the same for all mountains at the same latitude. (Generally, mountains closest to an ocean receive the greatest amounts of precipitation.)

5. Melted snow and glacial ice significantly contributed to creating the mudflows that followed the May 18, 1980, eruption of Mount St. Helens.

Materials

Demonstration

1. Potting soil, gravel, and water
2. Baking pan
3. Freezer
4. Bunsen burner

Activity 2 Continued

Work Session

1. Magazines
2. Large world map and push pins
3. Activity Sheet 4.2a–b
4. Transparency of "Snowline Diagram" (*fig. 2*)

Procedures

Demonstration

1. The **day before the demonstration**: In a baking pan, mix potting soil, gravel, and water to make a slurry. Place the baking pan in a freezer for at least 8 hours.

2. The **next day**: Bring the frozen slurry into class. Set it up at a steep angle. Hold a Bunsen burner under the high end of the baking pan. (*fig. 3*). Observe the pan at 3-minute intervals. Wait for the slurry to melt.

3. Point out to the students that this demonstration is similar to what happens when the heat of an eruption melts snow and ice on a volcanic mountain: water mixes with volcanic debris and creates mudflows.

4. Look at *poster figures 10* and *11* that show Mount St. Helens before and after the eruption.

Work Session:

1. Make a transparency of the "Snow Line Diagram" (*fig. 2).*

2. As a **homework or library assignment**, have students collect pictures of snow- and ice-covered mountains. Ask them to make a list of the names of the mountains and the countries or continents where they are located. (Collect your own group of photographs to make sure that all of the continents are represented.)

3. **In class**, make a list of continents on the chalkboard and compile the number of snow- and ice-covered mountains that the class found on each continent. Ask students if they expected to find snow-covered mountains in every continent.

4. Remind students that when Mount St. Helens erupted on May 18, 1980, it was capped by snow and numerous glaciers. Ask students if they would expect to see snow in May.

5. Distribute Activity Sheets 4.2a–b.

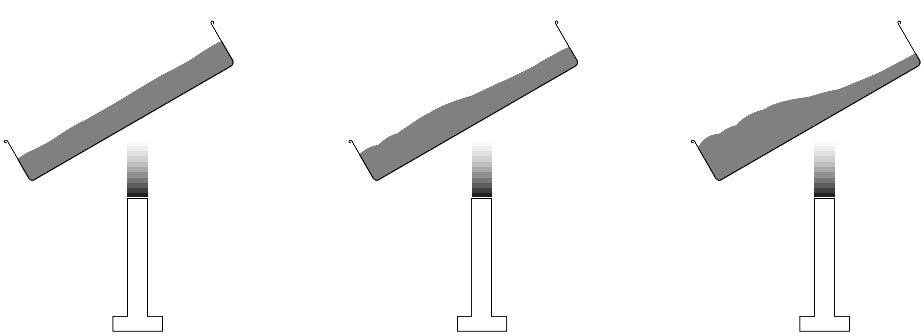
6. Students first label a group of volcanoes on a blank map. After they complete this part of the activity, **ask them to stop**.

7. Using a transparency, explain the "Snowline Diagram." This chart shows how the snowline varies with elevation and latitude. **To plot a volcano and find its snowline** :

- Find the approximate latitude of the volcano along the bottom of the chart and put a mark.
- Keep one finger on that spot and then find the approximate elevation along the right hand side of the chart.
- Put a mark where the two points come together. (For younger students, you may need to do this exercise as a class.)

8. Explain the concept of a snowline to the class.

fig. 3



Activity Sheet 2 Answers

Part A

2. Nevada del Ruiz
3. 4°N
4. Surtsey, 63°N

Part B

1.	Mount Vesuvius	No
2.	Mount Etna	Yes
3.	Kilauea	No
4.	Mauna Loa	Yes
5.	Mount Rainier	Yes
6.	Mount Fuji	Yes
7.	Mount Pelée	No
8.	Katmai	Yes
9.	Lassen Peak	Yes
10.	Parícutin	No
11.	Surtsey	No
12.	Sunset Crater	No
13.	Mount St. Helens	Yes
14.	Nevada del Ruiz	Yes

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VOLCANOES!

FIRE, ROCK, AND WATER

LESSON 4

fig. 1

Mount St. Helens

Mount St. Helens 2 years before its catcylsmic eruption. When the volcano exploded on May 18, 1980, huge volumes of snow and ice quickly melted and contributed to devastating floods and mudflows.

As hot volcanic debris melted snow and glacier ice on the upper slopes of Mount St. Helens, ***mudflows***—fast-moving mixtures of volcanic debris and water—developed within minutes of the beginning of the May 18 eruption. By 10:10 a.m. Pacific Daylight Time, a mudflow had traveled 43 kilometers (27 miles) downstream in the South Fork Toutle River valley. And before the day ended, nearly all the streams that had their sources on Mount St. Helens were affected by mudflows.

Fortunately, the major mudflow took hours to reach populated areas, giving people time to evacuate. As a result, only a few deaths were attributable to mudflows. Volcanic mudflows are also called ***lahars***, a term borrowed from Indonesia, where mudflows are a major volcanic hazard.

Mudflows’ Destructive Force

The largest and most destructive mudflow came down the valley of the North Fork of the Toutle River. It originated from the hot debris from the avalanche, lateral blast, and ash falls that had been deposited in the upper part of the river valley during the first few minutes of the eruption. By afternoon, water from melting snow and glacial ice, and from within the debris itself began to flow.

The mudflow steamed with hot volcanic materials (***pyroclastic debris***). Thick, like freshly mixed cement, the mudflow enveloped almost anything that it picked up along its path. Eyewitnesses reported seeing everything from ice chunks to a fully loaded logging truck in the flowing mixture. As debris, mud, and fallen trees choked the Toutle River, the river overflowed its banks and flooded, cresting at 6.4 meters (21 feet) above its normal stage.

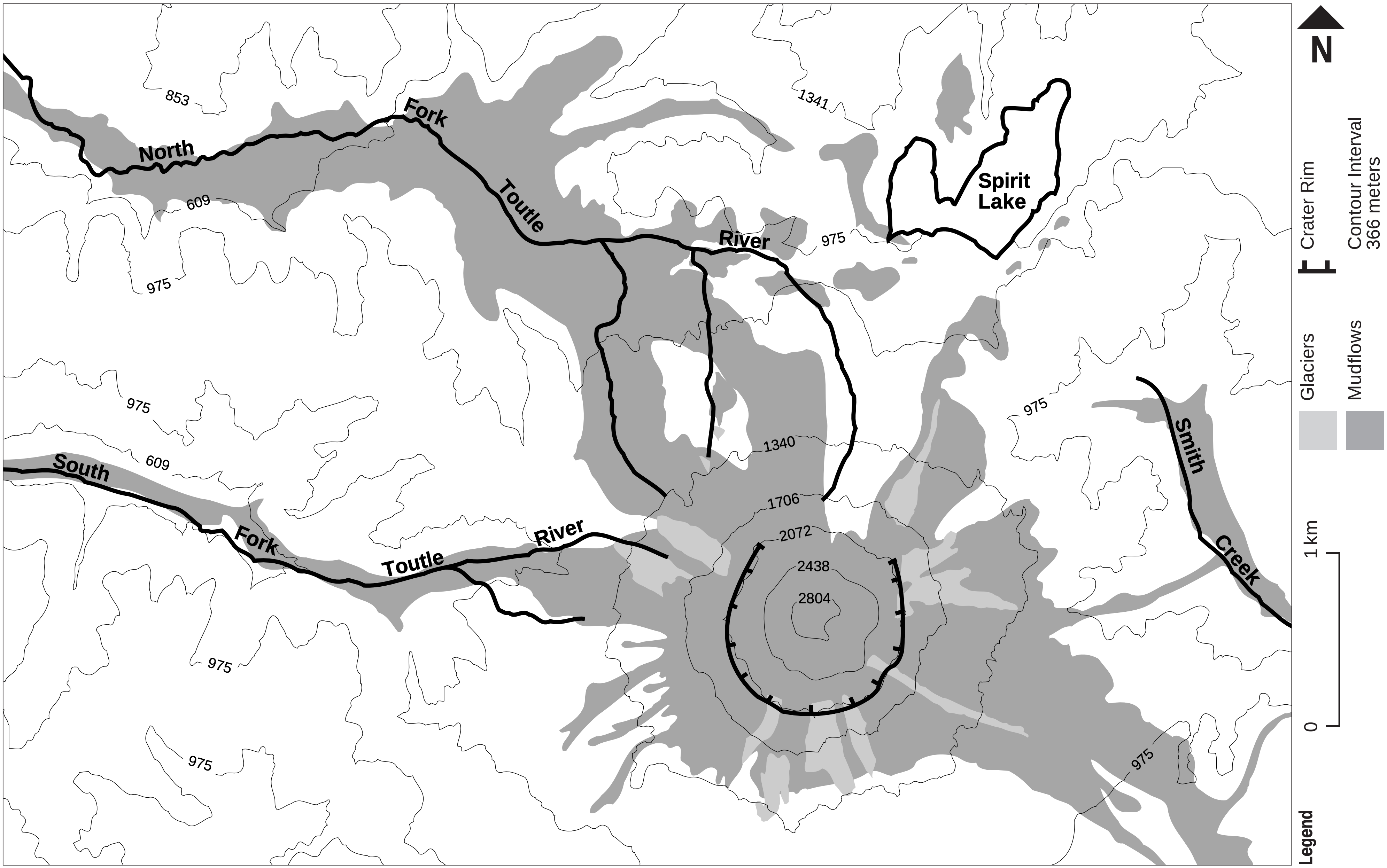
Snow and Ice Compound Dangers

Mudflows are particular hazards at snow-capped volcanoes such as Mount St. Helens. Even small eruptions of hot volcanic material can very quickly melt large volumes of snow and ice. The resulting surge of water erodes and mixes with volcanic rock to become mudflows. For example, the 1985 eruption of Nevada del Ruiz in Colombia was a very small eruption—ejecting only about 3 percent as much magma as Mount St. Helens—yet it generated high-volume mudflows because of the presence of snow and glacial ice on the volcano. The mudflows that swept down from Nevada del Ruiz buried the town of Armero, killing more than 23,000 people. Nevada del Ruiz, like Mount St. Helens, has snow and ice year round at its highest elevations.

The Risk of Mudflows Continues

Even without a major eruption, mudflows and floods remain potential hazards of Mount St. Helens. As a result of the May 18, 1980, eruption, huge volumes of volcanic debris dammed preexisting streams. Because these dammed streams are composed of loose materials, they are structurally weak. If the dams fail, mudflows and floods can occur. Loose volcanic debris on steep slopes is also vulnerable to flowing during or after heavy rainfalls. The risk of mudflows and floods is greatest on Mount St. Helens during the winter months when precipitation is heaviest and the snowpack is thickest.

Master Sheet 4.1



VOLCANOES!

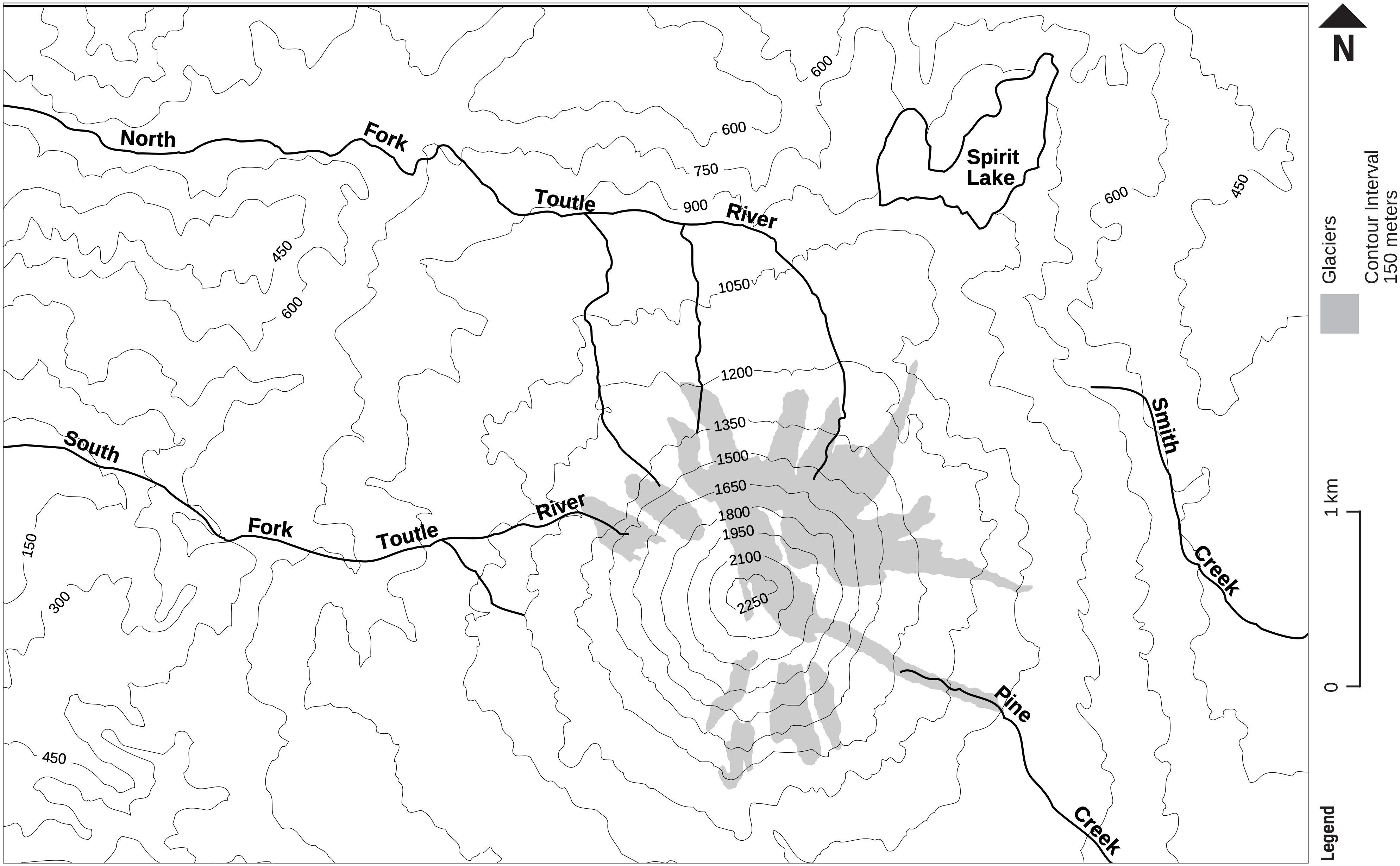
Activity Sheet 4.1a
Forecasting the Path of Mudflows

Destructive ***mudflows*** *began within minutes of the beginning of the May 18, 1980, eruption of Mount St. Helens. The mudflows look a lot like wet cement, but they can move as fast as 144 kilometers per hour (90 miles per hour) on a volcano's steepest slopes. In some places the mudflows were between 100 to 200 meters (30 and 60 feet) deep.*

What to do

1. Use the topographic map of Mount St. Helens to forecast the paths you think the mudflows took as a result of the May 18, 1980, eruption.
2. Color in the paths on your map.
3. Write a brief explanation to support your forecast.

Activity Sheet 4.1b
Forecasting the path of mudflows



VOLCANOES!

Activity Sheet 4.2a
The Snowline

*In some mountains, there are areas where snow and ice stay all year. The elevation above which the snow stays all year is called the **snowline.***

The snowline differs on volcanoes depending on how far a volcano is from the Equator and the volcano's elevation.

What to do — Part A

1. Label the volcanoes listed below on the blank map. (All the volcanoes are north of the Equator.) Write the volcano's elevation on the map.

Volcano	Location		Elevation in meters	
1. Mount Vesuvius	40N	14E	1,281	(Italy)
2. Mount Etna	37N	15E	3,350	(Italy)
3. Kilauea	19N	155W	1,222	(USA)
4. Mauna Loa	8N	157W	4,170	(USA)
5. Mount Rainier	46N	121W	4,392	(USA)
6. Mount Fuji	35N	138E	3,776	(Japan)
7. Mount Pelée	14N	61W	1,397	(Martinique)
8. Katmai	58N	154W	2,047	(USA)
9. Lassen Peak	40N	121W	3,187	(USA)
10. Parícutin	19N	102W	1,780	(Mexico)
11. Surtsey	63N	20W	155	(Iceland)
12. Sunset Crater	35N	111W	2,447	(USA)
13. Mount St. Helens	46N	122W	2,549	(USA)
14. Nevada del Ruiz	4N	75W	5,321	(Colombia)

2. Which volcano is closest to the Equator?

   ____

   What is its latitude?

   ____

3. Which volcano is farthest from the Equator?

   ____

   What is its latitude?

   ____

4. Would a volcano at 10°N be closer to the Equator than a volcano at 45°N?

   ____

   (**Latitude** shows us distance from the Equator.)

What to do— Part B

Use the Snowline Diagram to find out which of the volcanoes on your map will have snow on them during the summer.

1. For volcano #1, find its latitude along the bottom of the chart. Put a mark there.

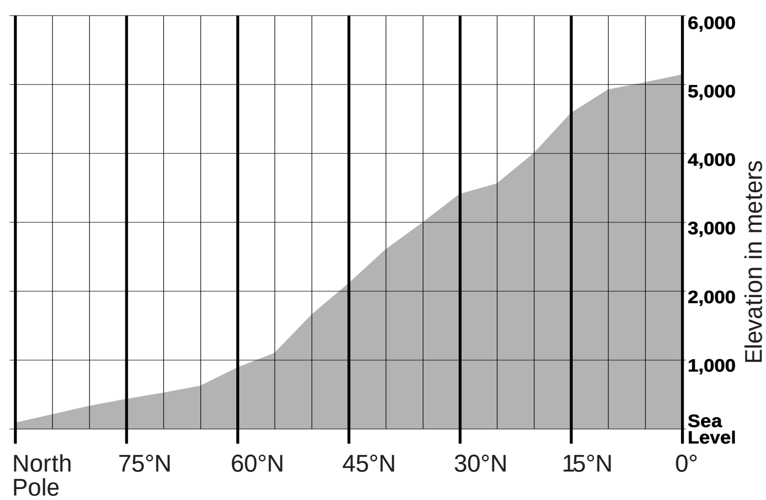
2. For volcano #1, find its elevation in meters along the right hand side. (Round off to the nearest thousand.) Put a mark there.

3. Put a mark where the two points come together. Is the mark above the dark area of the diagram? If yes, that volcano is likely to have snow on it during the summer.

4. If the volcano is likely to have snow on it during the summer, put a ✻ next to it on the list of volcanoes.

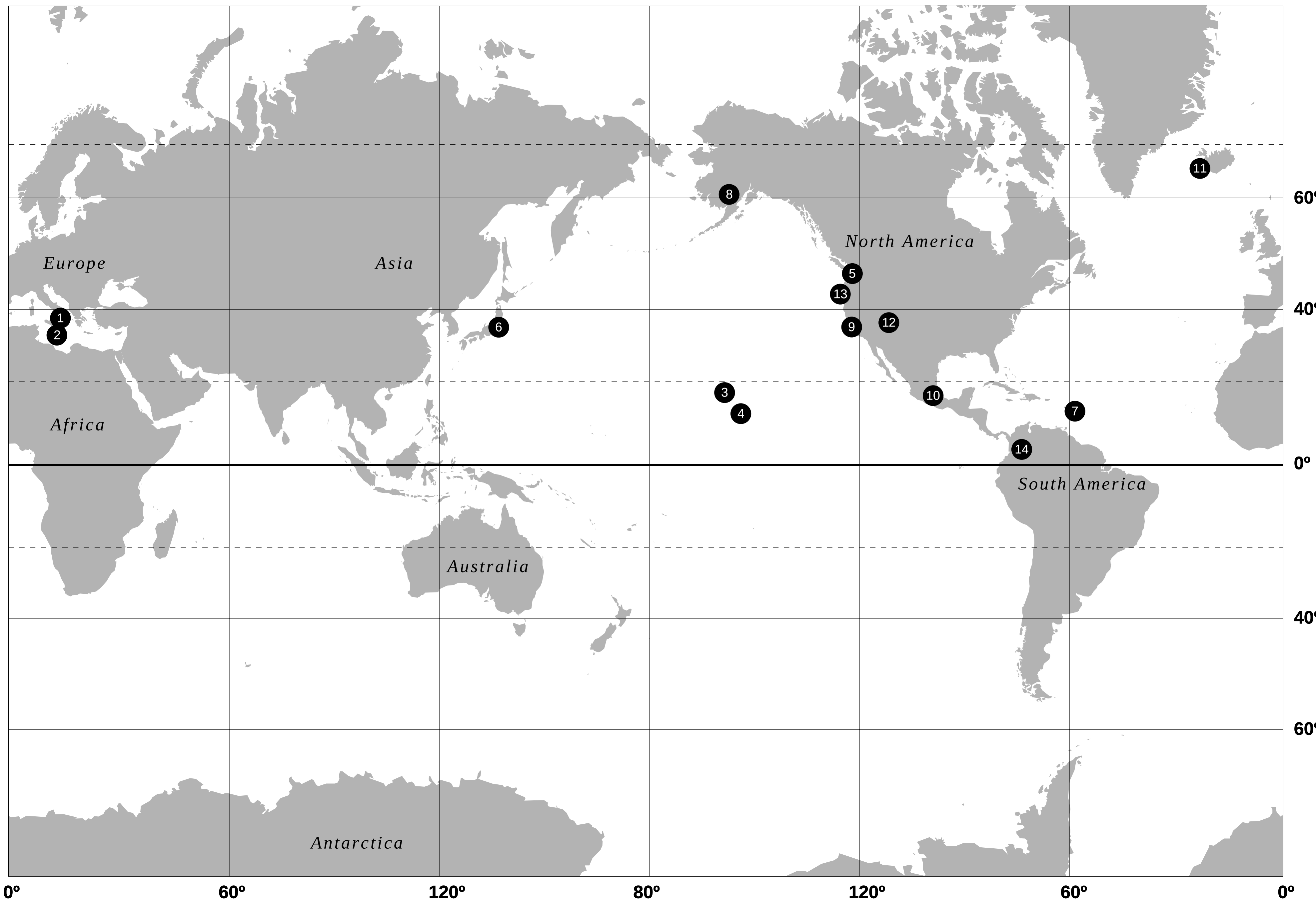
5. Repeat steps 1-4 for all of the volcanoes on the list.

Snowline Diagram



This diagram shows approximately how the elevation of the snowline changes with latitude.

Activity Sheet 4.2b
The Snowline



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DEATH AND RECOVERY

VOLCANOES!

LESSON 5

fig. 1

"This is It!"

"Vancouver, Vancouver, this is it!"

David A. Johnston, USGS volcanologist, was monitoring Mount St. Helens on a ridge north of the volcano. At 8:30 a.m. on May 18, 1980, he made his last radio transmission: No trace of him or his equipment has ever been found.

The Impact on Plants

The force of the lateral blast from Mount St. Helens' north flank blew down or snapped off trees within a radius of 25 kilometers (15 miles) north of the eruption site. At a distance of 25 kilometers (15 miles) from the blast, the force was no longer powerful enough to mow down trees, but it remained hot enough to kill the trees in its path. Ironically, some of the trees killed were old-growth Douglas firs 200 to 500 years old, which had survived previous eruptions.

Devastation in the wake of the avalanche was equally dramatic, although a few individual plants did survive, sprouting from root fragments that had been swept along on the surface of the debris. Plant survival in the path of the mudflows was likewise sparse. In addition, ashfall, which blanketed the forest to the northeast, smothered small plants and retarded the growth of larger ones.

The Impact on Animals

In the area affected by the blast, almost all wildlife vanished. Animals living above ground in the blast zone had no protection. Birds were particularly hard hit. Even those birds that survived the initial blast and avalanche died because the insects and plants they ate had perished. Insects were heavily affected, particularly by volcanic ash: the insects suffocated because ash clogged their body pores, or they dehydrated because glass-like ash abraded the cuticle that helps them retain moisture. Fewer than one-half of the small mammals species thought to have been living near Mount St. Helens were known to have survived. The death toll was nearly 7,000 large game animals, including deer, elk, and bear. The eruption severely damaged 26 lakes, killing an estimated 11million fish, as well as incalculable numbers of fresh-water invertebrates. The loss of human lives was 57.

Some Organisms Survived

The most surprising discovery following the eruption, however, was that many organisms survived in what appeared to be a lifeless gray landscape. In particular, plants sprouted in areas that had been protected under a snow cover and along stream banks and hillsides where erosion thinned ash deposits. Within a month, fireweed appeared from roots that had survived even though the tops of the plants were sheared off. Animals such as gophers and ants survived in their subterranean homes, while lake-dwelling frogs and salamanders escaped the blast under a protective cover of late winter ice.

The Recovery

Three years after the eruption, biologists had identified the recovery of more than 90 percent of the preeruption species of plants. Many plants owed their lives to gophers. These burrowing animals acted like garden tillers, by bringing the existing soil to the surface and mixing it with nutrient-rich volcanic ash deposited by the May 18, 1980, eruption. As the gophers dug, they also brought seeds, bulbs, and root fragments up to the surface where they could begin to grow. The "tilled" soil was also far more likely to trap seeds blowing across its surface.

Activity 1 Dating a Volcanic Eruption

Rich Volcanic Soils

Active volcanoes are also responsible for some of the world's most fertile soils. Tephra commonly contains potassium and phosphorus, two nutrients essential to plant growth. As tephra weathers, these nutrients are released into the soil, acting as a time-released fertilizer. The benefits of volcanic soils often lure people to risk living in the shadow of active volcanoes.

In the forests, ash initially retarded the growth of surviving trees, but as rains washed the ash off leaves and needles, growth recovered. The layers of ash that remained on the ground enhanced growth for several years. The ash had a mulching effect, keeping in check understory plants that normally compete with trees for water and nutrients. Because of its light, reflective color, a coating of ash can help soil retain moisture as well.

Although few large mammals survived in the blast zone, fresh deer tracks were seen within 10 days. Black-tailed and Roosevelt elk were among the game species that moved in from adjacent areas and took advantage of the surviving plants that were beginning to recover. Spirit Lake was black and putrid, but it was not dead—only different. Its waters had been taken over by opportunistic bacteria, feasting on tons of organic matter that had avalanched into the lake. Ten years after the eruption, half a million tree trunks still drifted across the lake's surface; but the recovery had been remarkable. Lake life had almost returned to normal.

Volcanic eruptions are a fact of life for forests at Mount St. Helens. Like wildfires, they are among various natural disturbances that continuously alter the growth of a forest and foster diversity. Without periodic clearing by natural causes, forests could not renew themselves.

45-minute work session
Students learn how to "read" tree rings to determine the date of a volcanic eruption and the effects an eruption has on plant growth.

Key teaching points

1. If you look at the top of a tree stump, you will see a series of concentric rings in the cross section of its trunk. Because a single ***tree ring*** is usually formed each year, tree rings can be used to date the tree.

2. Tree ring boundaries are distinguished by a change in appearance between the small thick-walled cells produced at the end of a growth season and the large thin-walled cells produced at the beginning of the next growth season. The wood between these boundaries is formed during one growth season and constitutes one growth ring. (*fig. 2*). Once the ring has formed, it remains unchanged during the life of the tree.

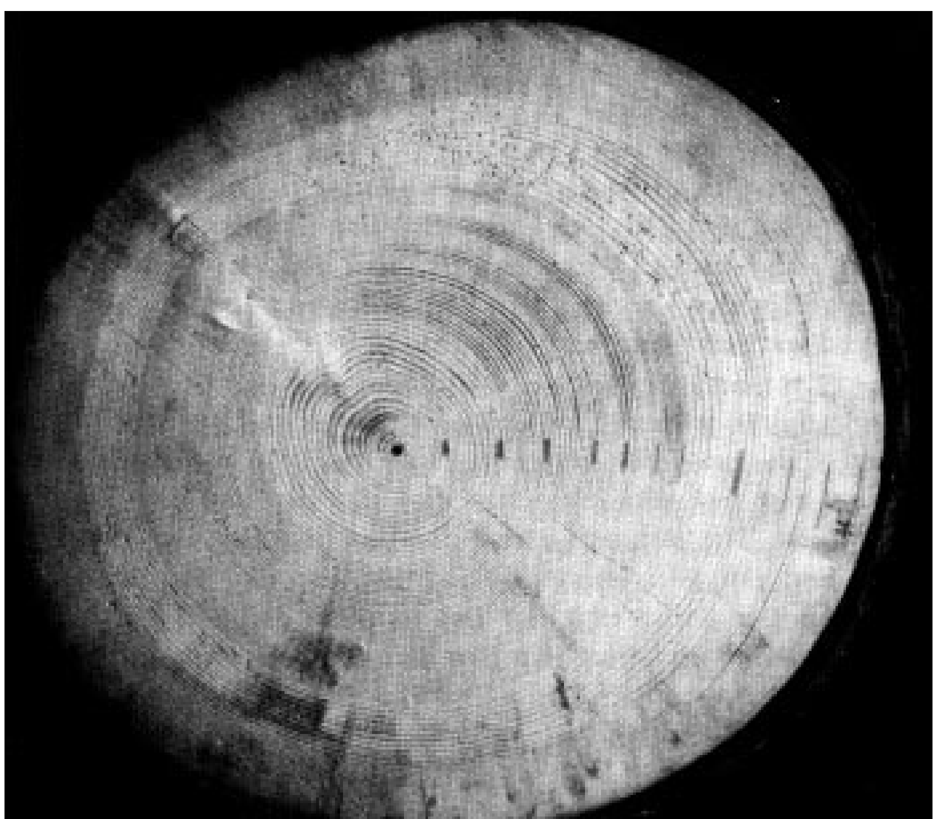
3. Scientists use tree ring data to help them establish the date of volcanic eruptions: the width of each year's growth records evidence of natural events, such as floods, drought, fires, and volcanic eruptions, that increased or decreased the width of that year's ring growth (*fig. 2*).

4. Tree rings record both the negative and positive effects of volcanic eruptions. After the 1980 eruption of Mount St. Helens, ash that blanketed forests to the northeast of the eruption retarded growth for about 2 years. As rain washed away the ash, the rate of tree growth recovered and actually increased. The effect of the ash was equivalent to putting mulch on garden plants —the mulch reduced competition for water and nutrients by plants in the understory (in a garden mulch helps retain moisture and keep weeds from competing with other plants.)

Materials

1. Activity Sheets 5.1a–b
2. Log with visible tree rings (optional)

fig. 2



This 120-year old tree records the 1912 eruption of Mount Katmai, Alaska.

Activity 2 Eyewitness Accounts

Procedures

1. Using either a piece of cut log or a diagram drawn on the chalkboard of a cross section of a tree, explain what tree rings are and what evidence they record about natural events that occurred during a tree's life.

2. Discuss the impact of the May 18, 1980, eruption of Mount St. Helens on the animal and plant life in the area around the volcano. Use *poster figure 20* to point out that a massive number of trees were killed during the eruption by the lateral blast, by forest fires started by lightning, and by avalanches and mudflows. Trees that survived, however, were charred or had their growth affected by the ash that covered the ground.

3. Distribute Activity Sheets 5.1a–b. Explain to students that they will use tree ring data to determine the date of an eruption of Mount Katmai in Alaska and the effect that the eruption had on the growth of a tree. (The tree's growth decreased for 3 years following the eruption but then increased for 12 years.) As a library assignment, they will make a time line and record on it important events that occurred during the life span of the Mount Katmai tree.

Extension

Have students draw tree ring patterns of their own and trade with other students to interpret.

Activity Sheet 1 Answers

1. 120 years
2. 1842
3. 1912
4. 3
5. 12
6. The ash helped to fertilize the soil

45- to 60-minute work session

In a **role-playing exercise**, students use eyewitness accounts to gather and evaluate information about the events of the May 18, 1980, eruption of Mount St. Helens.

Key teaching points

1. Many people who were in the vicinity of Mount St. Helens during the eruption were interviewed to gain information about the nature and sequence of events of the eruption.

2. Although somewhat subjective, these observations were an important component of the scientific investigation of the eruption.

Materials

1. Overhead projector
2. Transparency of Master Sheet 5.2a
3. Master Sheets 5.2a–d
4. Activity Sheets 5.2a–b (photocopy)

Procedures

1. Tell students that on May 18, 1980, people at many locations in the vicinity of Mount St. Helens witnessed the eruption of the volcano. They observed a wide variety of phenomena associated with the eruption, including an earthquake, a massive avalanche, the lateral blast, mudflows, and the fall of airborne materials (tephra, including fine-grained ash). As a review of previous lessons, ask students to name the phenomena they think the eyewitnesses would have seen, heard, or felt.

2. On an overhead projector, show a transparency of Master Sheet 5.2a that shows where the eyewitnesses were located when the eruption occured.

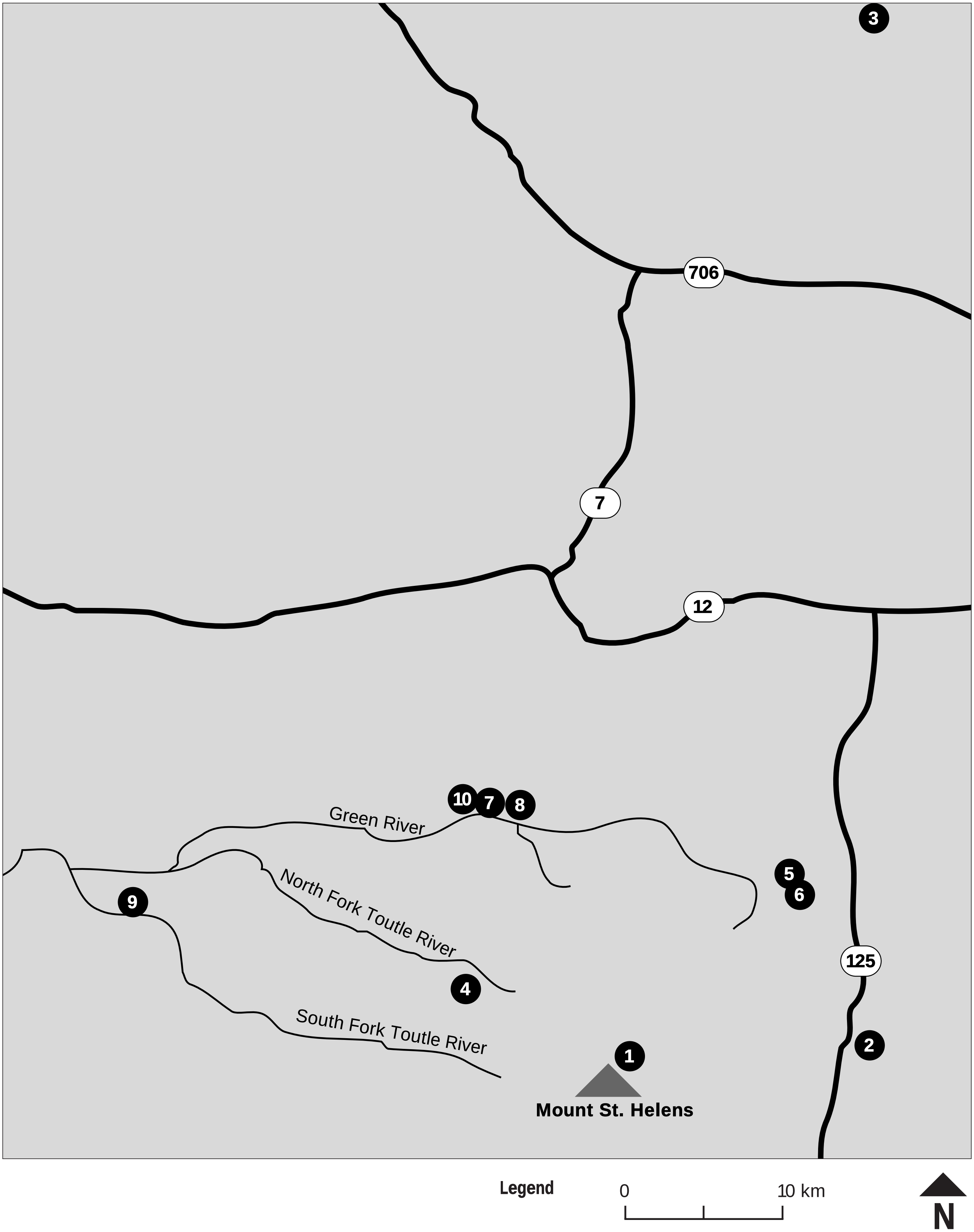
3. Students play the following roles: **reporter(s), eyewitnesses, and scientists** who are serving on a committee investigating the eruption.

4. Distribute one account to each of the eyewitnesses (see Master Sheets 5.2b–d). Ask eyewitnesses to read the accounts in preparation for being interviewed by a reporter. Encourage students to use props to help them relay their accounts. When they are interviewed, the students should answer questions in their own words.

5. Distribute Activity Sheets 5.2a–b to the scientists. Tell the scientists to take notes while listening to the interviews. After hearing all the interviews, they should list the similarities and differences among the accounts on their Activity Sheet.

6. Divide the scientists into groups of four to six students and ask each group to discuss their recollections of the eyewitness accounts. Eyewitnesses should circulate among the groups of scientists to answer questions. Each group of scientists should prepare a written summary that attempts to reconcile the eyewitness accounts.

Master Sheet 5.2a



Master Sheet 5.2b

These 10 accounts are listed in approximate chronological order corresponding to the sequence of the eruptive events. The number following the site location corresponds to the numbers on the map (Master Sheet 5.2a) showing the location of eyewitnesses.

Photocopy both sides. Cut up like note cards.

Eyewitness Account #1:
Name: K. and D. Stoffel (geologists)
Event witnessed: avalanche and beginning of the eruption
Site location: in a small aircraft directly over Mount St. Helens

"As we approached the summit, flying at an altitude of about 11,000 feet, everything was calm...Just as we passed above the western side of the summit crater, we noticed landsliding of rock and ice debris... Within a matter of seconds—perhaps 15— the whole north side of the summit crater began to move instantaneously...The entire mass began to ripple and churn up...then the entire north side of the summit began sliding north...We took photographs of this slide sequence occurring, but before we could snap off more than a few pictures, a huge explosion blasted out of the avalanche-detachment... We never felt nor heard a thing...From our viewpoint, the initial cloud appeared to mushroom laterally [sideways] to the north and plunge down. Within seconds, the cloud had mushroomed enough to obscure our view."

Eyewitness Account #3:
Name: J. Downing (climber)
Event witnessed: directed blast
Site location: 75 kilometers (47 miles) N/climbing on Mount Rainier at 3,200 meters (1,050 feet)

Climbers on Mount Rainier observed two distinct "flows," which began very shortly after the eruption started. These "flows" were described as clouds 300 to 600 meters (1,000 to 2,000 feet) thick that appeared to hug the ground. The heads of the "flows" disappeared into valleys and reappeared as they "hopped" over ridges. The earlier flow traveled to the west, perhaps down the North Fork Toutle River, and was followed almost immediately by a "flow" that seemed to travel to the east.

Eyewitness Account #2:
Name: P. and C. Hickson (geologists)
Event witnessed: avalanche and beginning of the eruption
Site location: 15 km (9 miles) E/Near road 125, east of Mount St. Helens

"As the avalanche reached the halfway point on the mountain, the summit eruption began with a dense black cloud followed by lighter gray material. A second eruption halfway down the slope occurred moments later." At this time the avalanche appeared to consist of upper and lower parts. The flank eruption was between the two. Seconds later the upper slide overrode the flank eruption and material was hurled far down the slope onto the lower slide. About 45 seconds after the avalanche began, the eruptive centers merged and the rapidly expanding cloud overtook the avalanche.

Eyewitness Account #4:
Name: C. McNerney
Event witnessed: directed blast
Site location: 13 kilometers (8 miles) NW/driving on south side of North Fork Toutle River

Following the collapse of the north side, a foglike ring (cloud) descended very quickly and expanded out from the mountain. At about 2 minutes after the beginning of the eruption, the witnesses began driving west at about 110-120 kilometers per hour (70-75 miles per hour). At this speed, they did not seem to get any farther away from the cloud. The wind blowing into the car was warm enough to give the impression that the car heater was on. They increased their speed to 135 kilometers per hour (85 miles per hour) and began outdistancing the cloud. About four kilometers (2.5 miles) farther west they stopped and could not see the black cloud. After a short time the cloud reappeared. The base of the black cloud looked "like avalanches of black chalk dust—first one part of the black cloud would shoot out in front, then another, then another, like waves lapping up on a beach." Pulling back onto the highway, they outran the cloud at about 105 kilometers per hour (65 miles per hour).

Master Sheet 5.2c

Eyewitness Account #5:
Name: W. and L. Johnson
Event witnessed: directed blast
Site location: 17 kilometers (10.5 miles) NE/on ridge top with good view of Mount St. Helens

Shortly after the vertical eruption began, a large horizontal blast occurred. Just before the top of the mountain became obscured, the south side of the summit crumbled into the hole formed by the avalanche. As the cloud grew, what appeared to be a shock wave similar to that associated with a nuclear explosion moved ahead of the cloud. About l 1/2 minutes after the start of the avalanche and perhaps 45 seconds after the start of the blast, a noise like a clap of thunder accompanied some sort of pressure change. The initial noise was followed by a continuous rumbling, "like a freight train."

Eyewitness Account #7:
Name: M. and L. Moore (campers)
Event witnessed: directed blast and ash cloud
Site location: 22 kilometers (14 miles) N/on north side of Green River

A noise similar to, but which "didn't sound quite right" for, a propeller-driven aircraft occurred for 10-20 seconds before a rapid pressure change, which caused ears to pop numerous times over a period of about 10 seconds. One person also felt as if she was being squeezed gently over her entire body. A short time later, an immense ash cloud approached that seemed to consist of a lower vertical wall and upper overhanging part.

Eyewitness Account #6:
Name: C. Rosenquist (amateur photographer)
Event witnessed: directed blast
Site location: 17 kilometers (10.5 miles) NE/ on ridge top with good view of Mount St. Helens

A rumbling noise began within 7-8 seconds of the start of the avalanche. One member of the group sensed a pressure decrease at about the same time. A "shock wave," which looked like heat waves, formed ahead of the blast cloud.

Eyewitness Account #8:
Name: B. Nelson (loggers)
Event witnessed: directed blast
Site location: 21 kilometers (13 miles) N/on north bank of the Green River

The witness and two companions were cutting timber with chain saws. Mount St. Helens was hidden by a ridge and the three men neither heard nor felt anything unusual until they were alerted to the eruption by a fourth man. About 10 seconds later, "a horrible crashing, crunching, grinding sound" came through the trees from the east. Suddenly, it became totally dark: " I could see absolutely nothing." It immediately got very hot, and almost impossible to breathe. While the men were gasping for air, the inside of their mouths and their throats were burned. The witness was knocked down, although he does not recall being hit by rocks or other projectiles. He arose with his back to searing, painful heat that lasted about 2 minutes. All trees had been knocked down, and everything was covered with about a foot of drab gray ash. None of the men's clothing had been burned, but their bodies had been burned extensively. Three of the men subsequently died. Heavy ash fall resumed after about 20 minutes.

Master Sheet 5.2d

Eyewitness Account #9:
Name: V. Dergan and R. Reitman
Event witnessed: mudflow
Site location: 40 kilometers (25 miles) NW/on the South Fork Toutle River

Sometime after 9:00 a.m. Pacific Daylight Time, the South Fork Toutle River began rising and quickly rose about a meter (3 feet). The river was slightly muddy and carried numerous logs. About 2-3 minutes after the first logs moved downstream, a railroad bridge moving at about 40 kilometers per hour (25 miles per hour) appeared. Trees were being snapped off. As the bridge went by, large logs behind it rolled up the bank. The mass of thick mud and logs pushed the witnesses and their car off the bank and into the river. They were swept along for about 5 minutes at about 40 to 50 kilometers per hour (25 to 30 miles per hour) in very thick, warm mud. The witnesses jumped from log to log toward shore where the flow was moving more slowly, and waded through warm mud over 5 meters (1.5 feet) deep. The mud continued to rise slowly for a short time. After perhaps 15-30 minutes the mud and logs stopped moving.

Eyewitness Account #10:
Name: B. Nelson and S. Ruff
Event witnessed: tephra fall
Site location: 21 kilometers (13 miles) N/on north bank of Green River

After the blast and a few minutes of clear sky, hot ash began to fall. Again, it became totally dark. This ash seemed to fall vertically. It was “like someone pouring a bag over your head.” The extremely heavy ash fall lasted about 15 minutes. The ash fall was so intense that the witnesses had to use their fingers to dig the ash out of their mouths. They put their shirts over their heads in an effort to keep the ash out of their mouths and noses. After 15-20 minutes “stuff started coming out of the sky.” They could hear this material hitting trees. One witness was hit on the head by something large enough to raise a lump. During the heavy ash fall, they became cold, sleepy, and nauseous, but did not suffer from headaches. After an hour and a half visibility began to return.

VOLCANOES!

Activity Sheet 5.1a
Dating A Volcanic Eruption

Have you ever looked at a tree stump and noticed its rings? Count the rings and you will know how old the tree is. Each ring represents 1 year in the life of the tree.

If you look closely at **tree rings***, however, you will see that the spaces between rings vary in width. Trees do not grow the same amount each year.*

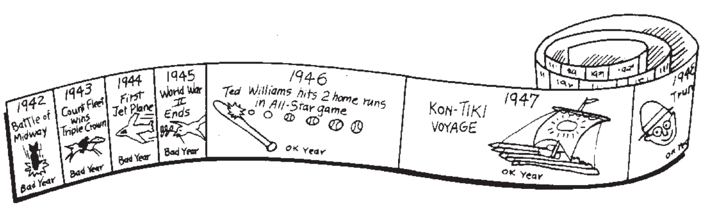
What to do

You can “read” these tree rings and find out what year there was an eruption of Mount Katmai in Alaska.

What you know:

1. This tree was growing 48 kilometers (29 miles) northwest of Katmai Volcano.
2. After the eruption, the forests were blanketed in ash.
3. This tree’s growth decreased for some years after the eruption, but then it increased.
4. This tree was cut down in 1962.

Make a time line for the years that this tree was alive. Research and record events that occurred during the tree’s life.



What you want to find out:

1. The tree’s age:

   ____

   (Count the number of rings from the center of the tree to the bark. Each dark band represents 10 years.)

2. The year the tree started to grow:

   ____

1962 –	____________ =	____________
the year the tree was cut down	*the age of the tree*	*the year the tree started to grow*

3. The year of the eruption:

   ____

   (Count the number of rings from the center to the first thin ring.)

4. The number of years the tree’s growth decreased:

   ____

   (Count the number of thin tree rings)

5. The number of years the tree’s growth increased:

   ____

   (Count the number of wide rings.)

6. Why do you think the tree’s growth increased?

   ____

   ____

   ____

   ____

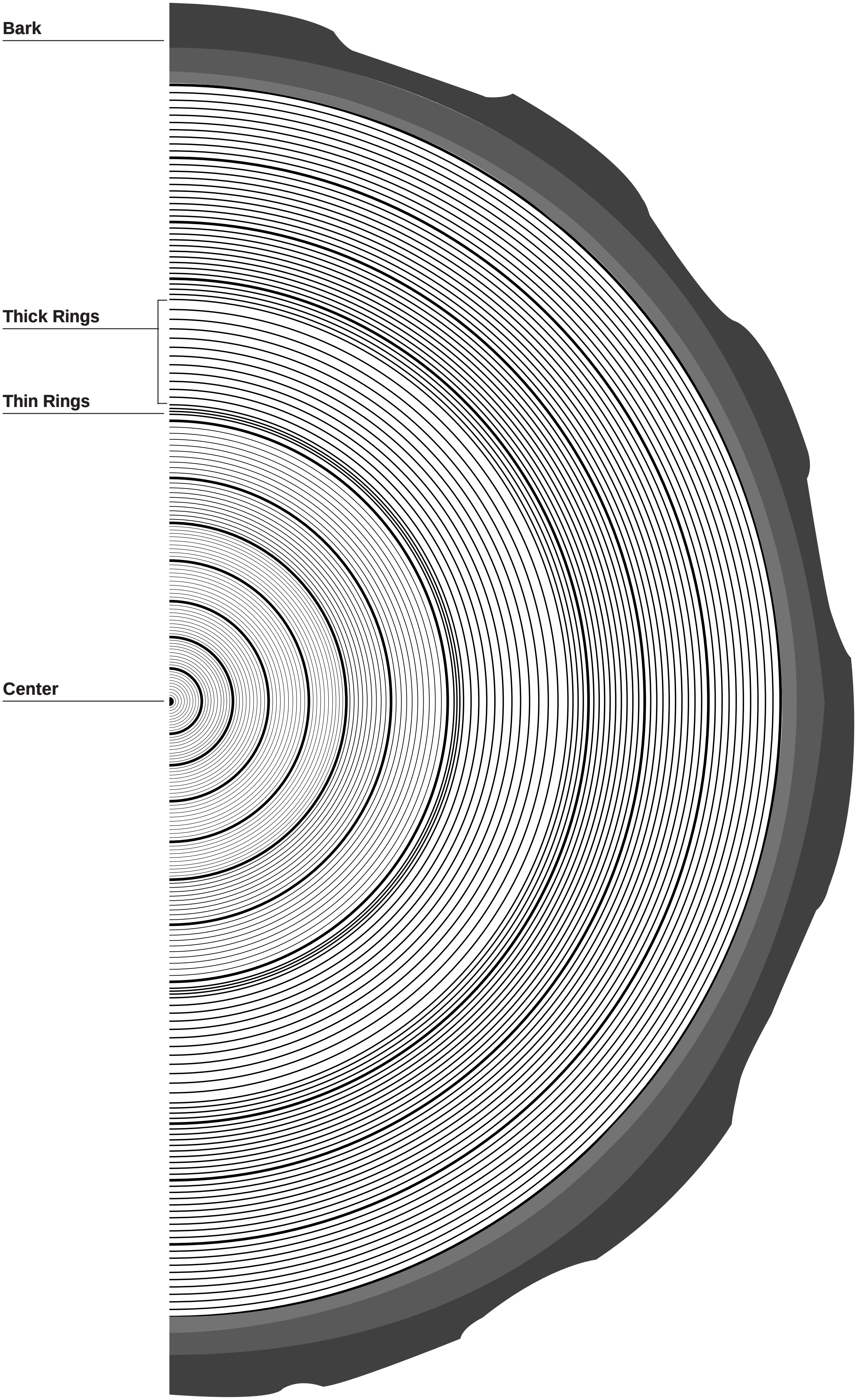
   ____

   ____

   ____

VOLCANOES!

Activity Sheet 5.1b
Dating A Volcanic Eruption



VOLCANOES!

Activity Sheet 5.2a
Eyewitness Accounts

What to do

For each eyewitness, write in the spaces provided: the name, approximate location during the eruption, and important statements the eyewitness makes about the eruption.

These accounts were excerpted from the "Summary of Eyewitness Accounts of the May 18 Eruption," by J.G. Rosenbaum and Richard B. Waitt, Jr., in The 1980 Eruptions of Mount St. Helens, Washington, *USGS Professional Paper, 1250.*

Eyewitness # ____________________

Name ____________________

Location ____________________

Statements ____________________

Eyewitness # ____________________

Name ____________________

Location ____________________

Statements ____________________

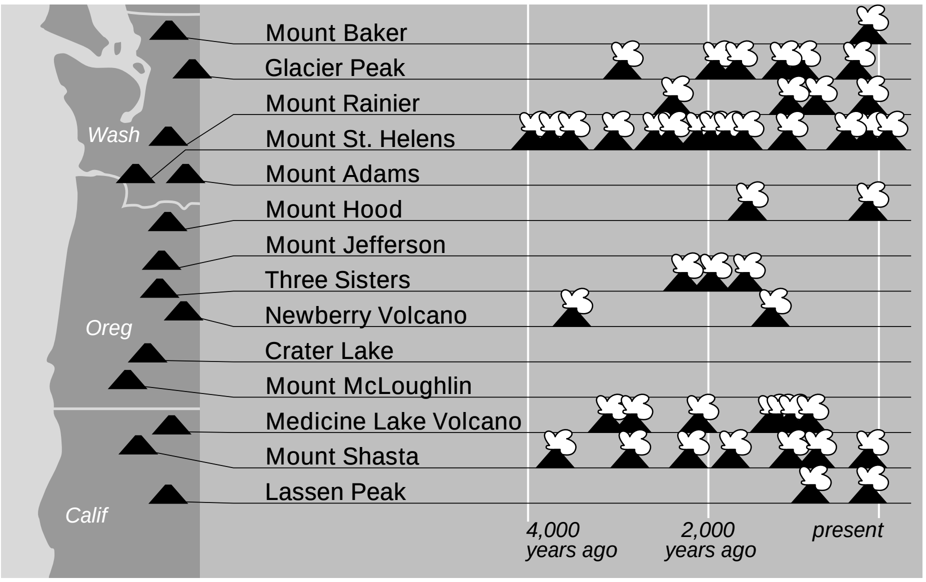
Activity Sheet 5.2b
Eyewitness Accounts

	Similarities	Differences
Eyewitness #1		
Eyewitness #2		
Eyewitness #3		
Eyewitness #4		
Eyewitness #5		
Eyewitness #6		
Eyewitness #7		
Eyewitness #8		
Eyewitness #9		
Eyewitness #10		

Activity 1
Creating a Legend

fig. 2

Cascade Eruptions



Eruptions in the Cascades have occurred at an average rate of one to two per century during the last 4,000 years. Four of those eruptions would have caused considerable damage and loss of life if they had occurred today without warning.

still present beneath the volcano. On average, it has erupted once every 300 years over the past 3,500 years. The chance is 1 in 25 to 30 that it will erupt in any one decade and 1 in 3 or 4 within a person's lifetime.

Forecasting Future Eruptions

Scientists have improved their ability to predict the time of a volcanic eruption, but estimating the size and style of an eruption remains a difficult challenge. Despite this challenge, scientists try to assess the potential consequences of a future eruption by reconstructing a volcano's history, which includes the pattern, magnitude, and frequency of its past eruptions. The principal means of developing this history is by mapping and dating the different types of volcanic materials that have been deposited by previous eruptions. Assembled into volcanic hazards maps, this information is vital for communities in volcanically active areas to use for land use and emergency preparedness planning. Knowing a volcano's past is crucial to forecasting its future behavior.

Benefits Often Overlooked

Because of the destructive nature of a volcanic eruption, we tend to overlook a volcano's benefits. Magma circulates and deposits many valuable elements, such as gold, silver, zinc, sulfur, and copper. Magma heats ground water systems that can be tapped to produce geothermal power. This heated ground water can also result in geysers and hot springs. Volcanoes are also responsible for some of the world's most fertile soils. And volcanoes continuously bring materials from inside the Earth to the surface—recycling on a grand scale.

45 minutes
Students create a legend that explains the existence of Mount St. Helens.

Key teaching points

1. Mount St. Helens has been a fact of life for people living in its shadow ever since humans began populating the Pacific Northwest more than 10,000 years ago. There have been dozens of eruptions during the past 4,500 years.

2. Before there were scientific explanations for why volcanoes erupted, people developed stories to explain the presence and behavior of volcanoes.

3. The Yakima Indians called the volcano "Tah-one-lat-clah" (Fire Mountain). The Cowlitz people called it "Lawetlatla" (Person from Whom Smoke Comes). Its modern name, Mount St. Helens, was given to the volcano in 1792 by Captain George Vancouver of the British Royal Navy.

Materials

None required.

Procedures

1. Tell the legend below that was created by the Yakima people. (Before European settlement in the 19th century, the Yakima people had considerable territory on the Yakima and Columbia Rivers in Eastern Washington. Today, descendants of these people live on the Yakima Indian Reservation in south-central Washington.)

Two tribes lived across the river from one another. Because they were friendly and peaceful tribes, the Great Spirit built a bridge across the river for them. Eventually, however, the tribes began to quarrel. The Great Spirit became angry. To punish the tribes he took away fire. The tribes prayed to the Great Spirit to return fire to them. Finally, the Great Spirit agreed. To restore fire, the Great Spirit had to go to an old woman named Loo-Wit who, because of her goodness, still had fire. Loo-Wit promised the Great Spirit that she would share her fire with the two tribes if the Great Spirit would

Activity 2
There's a Volcano in my Backyard!

make her eternally young and beautiful. Fire was restored, and the tribes were peaceful for a short time. The chiefs of both of the tribes, however, fell in love with the beautiful Loo-Wit. The chiefs began to quarrel and went to war. Once again, the Great Spirit became angry and in retaliation he turned the two chiefs into mountains. One became Mount Hood and one became Mount Adams. Because Loo-Wit was so beautiful, the Great Spirit made her into Mount St. Helens—that way she could remain beautiful forever.

2. Students discuss how the legend differs from the way we now explain how volcanoes form. Are there similarities between the legend and scientific explanations?

3. Ask students to imagine that they live in a time and place where there are no scientific explanations for why there is an active volcano near their community. Students create and present orally a short legend to explain why the volcano exists or erupts.

Extension

Do research from the journals of George Vancouver, John Fremont, and other explorers to the Pacific Northwest to learn their descriptions of Mount St. Helens and other volcanoes in the Cascade Range. Using these accounts as a basis, students create their own diary entries.

45-minute work session
one followup project
Using a volcanic hazard map of Mount Rainier, students reach conclusions about the potential hazards of future eruptions. They then create educational materials about these hazards.

Key teaching points

1. Mount Rainier is located 35 kilometers (21 miles) southeast of the Seattle-Tacoma metropolitan area—an area that has a population of 2.5 million.

2. Mount Rainier is an active volcano whose last major eruption was approximately 150 years ago.

3. Mount Rainier has five times as much snow and glacier ice as all the other Cascades volcanoes combined. Mudflows are the most dangerous hazard.

4. Throughout the volcano's history, there have been numerous mudflows. Today, parts of Tacoma, Wash., and many other smaller communities have been built on top of these old flows—evidence that they lie within the reach of future mudflows that could originate from an eruption of Mount Rainier.

5. An eruption of Mount Rainier could kill hundreds of thousands of people and cripple the region's economy.

Materials

Activity Sheet 6.2

Procedures

Work Session

1. Review with students that Mount St. Helens is one of a number of active volcanoes in the Cascade Range. Some others include: Mount Baker, Mount Rainier, and Mount Adams in Washington; Mount Hood, Mount Jefferson, and Crater Lake in Oregon; and Mount Shasta and Lassen Peak in California.

2. On a large map, locate Mount Rainier and locate cities within 80 kilometers (50 miles) of it.

3. As a class, list the major eruptive events (include avalanches, mudflows, and tephra falls) that occurred during the 1980 eruption of Mount St. Helens.

4. Using an overhead projector, show students the eruptive history map of Mount Rainier (see Activity Sheet 6.2). Explain that scientists study past eruptions to help them forecast future eruptions. Looking at this map, what type of eruptive events have occurred in the past.

5. Distribute Activity Sheet 6.2. Tell students they will look at Mount Rainier's history of volcanic mudflows and forecast if there are any cities that would be at risk during a future eruption.

6. Discuss: What cities, if any, would be at risk if there were a future eruption? Is it possible, or practical, to eliminate all risks to these cities? What things can be done to reduce risks to life and property? Conclude that public education is a major activity.

Followup Project

Students work individually or in teams to develop a range of educational materials and programs for the general public, especially school children. These might include posters; displays for schools, public libraries, and community centers; brochures; public service announcements on TV and radio; and information on the Internet.

Activity Sheet 2
Answers

Osceola Mudflow
2. 70 kilometers
3. Enumclaw

Electron Mudflow
2. 50 kilometers
3. Ortig and Puyallup

U.S. Department of the Interior
U.S. Geological Survey

VOLCANOES!

VOLCANOES AND PEOPLE

LESSON 6

fig. 1

Mount Rainier

Snow-capped Mount Rainier rises behind Tacoma, Washington. Although Mount Rainier has not erupted in the past 500 years, scientists consider it one of the most hazardous volcanoes in the Cascade Range.

Relative to other types of natural disasters, such as earthquakes, floods, hurricanes, and tornados, volcanic eruptions occur infrequently. Of the 1,500 active volcanoes on land, approximately 50-60 erupt each year. Approximately 1 million people have been killed by volcanic eruptions during the past 2,000 years.

United States Has Many Active Volcanoes

Because many of the most hazardous volcanoes have not erupted during recent historic times, people erroneously consider them extinct. For Mount St. Helens, more than a century had elapsed since a major eruption; most people were not aware of its dangers. Mount St. Helens is one of more than 65 active or potentially active volcanoes in the continental United States, Alaska, and Hawaii. Only Indonesia and Japan have more!

Scientists of the U.S. Geological Survey continue to monitor Mount St. Helens and other volcanoes in the Cascade Range. They know from its past eruptive history that many of Mount St. Helens' eruptions have occurred in concentrated periods of time lasting decades or even centuries. For example, one eruptive phase began in 1480 and lasted for about 300 years. Based on that history, scientists anticipate that Mount St. Helens will continue to erupt episodically for decades to come before it returns to a dormant stage.

The eruption of Mount St. Helens served as a reminder that other dormant volcanoes can come to life again. Mount Shasta in Northern California, for example, probably last erupted in 1786. On a geological time scale, this very recent volcanic activity suggests that magma is

VOLCANOES!

Activity Sheet 6.2
There's A Volcano in My Backyard!

Mount Rainier is an active volcano in the Cascade Range. During past eruptions large mudflows resulted. If similar mudflows occurred in the future, would people be in danger?

What to do

Osceola Mudflow
(occurred about 4,500 to 5,000 years ago)

1. Find the Osceola Mudflow on the map. Trace the course of the mudflow from where it began on the slopes of the volcano to where it ended.

2. How many kilometers did it travel?__________

3. What cities would be in danger if the Osceola Mudflow occurred today?______________________________

Electron Mudflow
(occurred about 550 years ago)

1. Find the mudflow on the map. Trace its course from where it began on the slopes of the volcano to where it ended.

2. How many kilometers did it travel?____________

3. What cities would be in danger if the Electron Mudflow occurred today?_________________